Technical Report 1322

Developing Training Exemplars for the Requisite Components of Visual Threat Detection

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In the first stage of this research, a model of visual threat detection, the threat detection loop, was developed and requisite components of that model identified (Zimmerman, Mueller, Grover, & Vowels, In Preparation). The primary components of visual threat detection were determined to include dynamic threat monitoring, threat prioritization, and causal reasoning. This second report describes a final quasi-experiment involving those primary components. Results from all research informed the development and refinement of a training exemplar that consists of exercises involving each of the components. The exemplar was improved based on feedback from Soldiers with operational experience and from instructors/trainers with involved in training threat detection skills.

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threat detection, causal reasoning, irregular warfare, attention, memory

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DEVELOPING TRAINING EXEMPLARS FOR THE REQUISITE COMPONENTS OF VISUAL THREAT DETECTION

EXECUTIVE SUMMARY

Research Requirement:

Visual threat detection continues to be a necessary task carried out by Soldiers in the operational environment on the majority of (if not every) mission. In this research, the primary processes of visual threat detection were explored to improve understanding and provide a substantive model upon which further research could be conducted. As Soldiers are tasked to operate within and around local populations, it is imperative that they have a solid understanding of what cues represent likely threats and deserve the appropriate attention and response.

Procedure:

Stimuli were refined from previous research and used in a final experiment. The final experiment allowed for a test of the threat detection loop which is the model of expert threat detection developed in the first phases of this research. Soldiers participated in several computer-based exercises and then took part in semi-structured interviews where they provided feedback on their experiences involving visual threat detection. Those results were incorporated with the previous findings and were used in the development of a training exemplar. The exemplar was refined based on a formative evaluation in which Soldiers and trainers provided feedback on usability and content.

Findings:

The results revealed that the threat detection loop is a viable conceptualization of experience-based threat detection. As Soldiers gain experience with the primary components of threat detection, they develop expertise and are better able to discern what constitutes a valid threat in operational settings. Both quantitative and qualitative results suggest that experience, as described by the model, does positively impact the ability to visually search for and make a determination about threat cues and overall threatening situations. Soldiers and instructors/trainers provided constructive feedback on the training exemplar; they, likewise, noted that the exemplar would be useful for newer, less experienced Soldiers as well as for combat veterans who might need re-training on threat detection skills prior to deployment.

Utilization and Dissemination of Findings:

The model developed for this research can be used to guide further research on visual threat detection. The materials developed to test the model can also be used to explore future questions to improve understanding of visual threat detection. The research based training exemplar can be distributed to operational units to bolster existing training or stand alone as an example demonstrating the primary components of visual threat detection. The exemplar was transitioned to a deployed Brigade Combat Team (BCT) to enhance their training in theater as

well as to a training support battalion to augment extant training that battalion offered as part of their pre-mobilization training regimen.

DEVELOPING TRAINING EXEMPLARS FOR THE REQUISITE COMPONENTS OF VISUAL THREAT DETECTION

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DEVELOPING TRAINING EXEMPLARS FOR THE REQUISITE COMPONENTS OF VISUAL THREAT DETECTION

Introduction

Threat detection is an important skill that United States Army Soldiers must utilize when working in the Operational Environment (OE). Recognizing that the ability to detect threats is vital, the Army has focused on developing technologies to assist Soldiers in extending this capability. While certain technologies, like unmanned aerial vehicles, can be particularly useful for providing a bird's eye view of an area of operations, they may not always be available. Moreover, these technologies are intended to augment, not replace the human ability to detect threats. Threat detection relies on a number of perceptual skills such as attention management, pattern matching, and change detection as well as higher-order cognition. Humans must reason about the threats, incorporating their previous experiences and knowledge about the context to assess whether a particular cue might indicate a potential threat.

A large body of scientific research provides empirical evidence that can guide our understanding of how these skills should manifest in the OE with Soldiers of varying experience levels. Leveraging this research base, several related research projects were conducted to better understand and, ultimately, improve visual threat detection performance in the OE. By relying on current psychological theories of visual attention and expertise, military doctrine, and Soldiers' threat detection experiences during recent deployments, this research aimed to achieve a greater understanding of how Soldiers detect threats in the OE. Culmination of that information resulted in the development of a threat detection model, the Threat Detection Loop, which is discussed in the next section. The objective was to use this improved understanding of the threat detection process to create training to enhance Soldiers' threat detection performance. The goals of this research were to:

- identify the cues, skills, and strategies required to detect threats in the OE,
- differentiate the cognitive skills employed by experienced versus novice Soldiers, and
- create training exemplars that enhance the cognitive threat detection skills of Soldiers.

This report presents a culminating experiment intended to tie together our research in this area and provides details about the training exemplar developed to enhance Soldiers' threat detection skills. The purpose of the experiment was to test the cognitive and perceptual skills of Soldiers who had varying levels of experience detecting threats in the OE. Soldiers in this experiment had experience levels ranging from zero to four deployments. To test their skills, Soldiers completed a series of computer exercises that examined their performance while doing (a) prioritized threat search, (b) dynamic threat detection, and (c) change detection. This research also sought to identify any differences in reasoning about potential threats in the context of various OE relevant situations. Soldiers participated in interviews and discussed the threat cues and situational elements depicted in photographs of U.S. troop activities and terrain in Iraq and Afghanistan.

A previous report documented the procedures and findings of the first research phases conducted (Zimmerman, Mueller, Grover, & Vowels, In Preparation). The initial step toward understanding threat detection in the OE was to review the scientific literature and gather information about the cognitive and perceptual processes that factor into threat detection. Analysis of this research provided insight into the mechanisms that lead to threat detection and guidance on how to improve threat detection. Three preliminary research phases followed the literature review. The purpose of these research phases was to investigate the cognitive processes of Soldiers during threat detection exercises and gather information from experienced Soldiers about threat detection in the OE. Findings from these research phases formed the foundation of the current experiment and the training exemplar.

The research in Phase I provided initial understanding of threat detection in the OE. Soldiers at Fort Hood, TX, participated in interviews and completed questions (Phase 1a) and police officers on patrol participated in ride-along observations (Phase 1b). This initial research provided information about threat detection situations and activities in the OE and the case-study account of patrol activities by police officers provided insight into situations with high threat likelihood. The results from this research supported the findings highlighted in the literature review about the importance of threat search, change detection, and attention management when trying to detect threats. Observations of police officers with varying levels of experience provided examples of threat detection that occurred in their patrol environments. Those environments required constant vigilance to detect, assess, and react to potential threats. The findings illustrated possible differences in threat detection processes of less and more experienced threat detectors.

In Phase II, Soldiers provided data by completing an imagery analysis exercise, questionnaires, and in-depth interviews. This allowed for a test and refinement of research materials and development of a threat detection model. In the imagery analysis exercise, Soldiers identified areas of potential threats and annotated these areas with reasons why these areas were a concern. This analysis provided information about the regions of interest, threat cues, and explanations about the threats. From this, materials were created to measure attention management, threat search activities, and causal reasoning about threat environments. In the questionnaires, Soldiers from combat arms, combat service, and combat service support reported similar levels of concern and difficulty across the different types of threats, with the greatest concern being for relevant operational threats such as Improvised Explosive Devices (IED) and suspicious persons and vehicles. During interviews, Soldiers discussed how they gather information, spot cues and trends, scan environments, observe changes, aggregate information, and form mental pictures of situations. Their descriptions of the types of threats and cues present in threat situations feed into research stimuli development and informed the exercises Soldiers would complete in the experiments that followed. In addition, these data contributed to the development and refinement of the threat detection loop that represents a threat detection mental model and illustrates the threat detection process.

Phase III was a preliminary assessment of the refined research materials. These materials included exercises focused on dynamic threat monitoring/search, threat prioritization, and causal reasoning. Soldiers completed the exercises and provided feedback about the accuracy and relevance of the materials. They discussed the photos presented during the exercises and provided interpretations of the threats present in the photos. They also reasoned about why the threats were important, rated the degree to which the threats are likely to come to fruition, and described how they would handle similar threats based on their experiences. These findings, as well as feedback from the Soldiers about the exercises, indicated that the materials developed would provide a good test of threat detection skill and the photos and exercises were relevant to current threat detection activities in the OE.

This report presents the findings from the final research phase and consists of a discussion of the design and development of the training exemplar, including a formative evaluation and suggestions for refinements and extensions of the research and training. The report presents information as follows:

- introduction: the remainder of the introduction will discuss the threat detection loop and research on expertise development,
- research: including discussion of the experiment methods, procedures, and results,
- training design and development: the design includes the process for identifying training stimuli and content, and the development includes construction of the computer-based training exemplar and results of two formative evaluations, and
- designs for refinements and extensions: this section suggests the use of eye-tracking technologies and immersive environments to expand our understanding of threat detection by examining threat detection performance in more realistic settings such as, during field-exercises and in Combat Training Centers.

Threat Detection Model

An analysis of the literature and of findings from the initial phases of this research (Zimmerman et al., In Preparation) led to the refinement of a threat detection loop that represents the cyclical process engaged in during threat detection. Findings suggested that the primary components of visual threat detection are (See Figure 1):

- dynamic threat monitoring or maintaining a vigilant search of the environment among competing visual cues,
- threat prioritization or identifying threat-relevant versus threat-irrelevant cues, and
- causal reasoning or determining why certain cues are present or, for instance, what the enemy may interpret as a good concealment location.

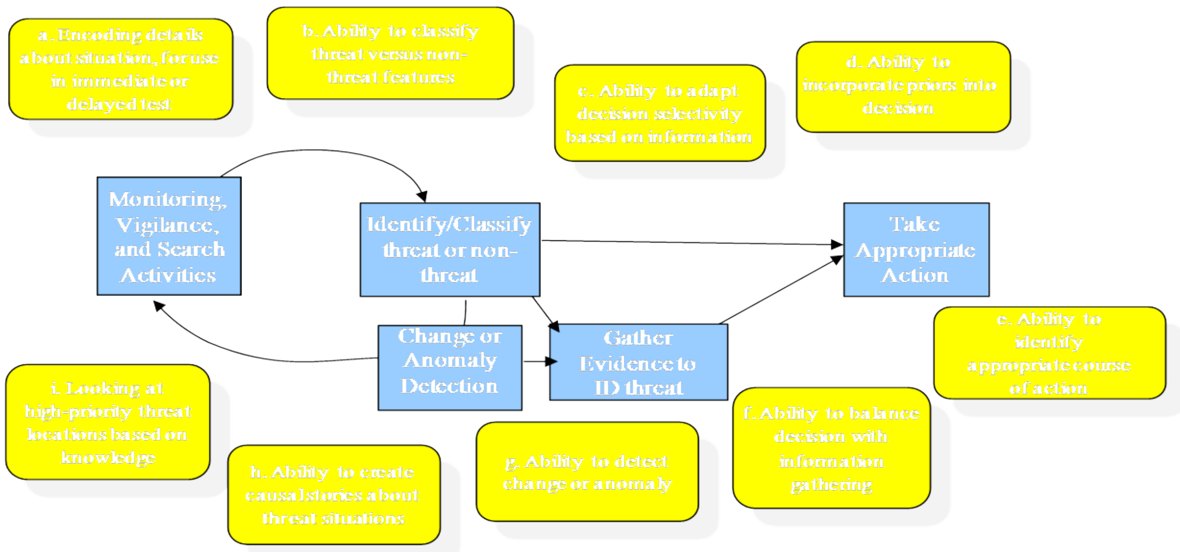

Figure 1. Threat Detection Loop (inner rectangles) and measurable behaviors of expert threat detection skill (outer rectangles).

Figure 1 depicts steps in the threat detection loop (inner rectangles) and their corresponding behaviors or abilities (outer rounded rectangles). For instance, to effectively monitor and search activities (loop) threat detectors need to encode relevant details (a). Based on an understanding of visual features related to threats, experienced threat detectors should be able to classify threats accurately and quickly (b). The loop indicates that experienced threat detectors are likely to see patterns during visual search that match to their prior experiences, and thus demonstrate better ability to locate and classify high priority threats (i). Their prior experience should influence their decisions as they determine an appropriate action (d) and enhance their ability to detect changes and anomalies in their environments (g). Based on experience, these threat detectors should also demonstrate ability to construct causal stories about situations (h) and predict how the threats might materialize. This ability to incorporate information and construct stories should allow them to identify and classify threats in a selective manner (c), which would influence their decision threshold for taking action. Threat detector ability to weight the strength of the evidence regarding presence and severity of potential threats (f) also influences this threshold. Because threat detectors can incorporate their experiences as they process relevant information to identify threats, this model predicts they will demonstrate ability to identify appropriate courses of action (e).

The loop consists of several processes that Soldiers develop as they acquire threat detection knowledge and experience. Because the research conducted in Phases I through III focused on exercises such as threat prioritization and causal reasoning, the data revealed informational cues and experiences that are most important for gaining knowledge and developing the ability necessary for visual threat detection. To identify the processes that form the threat detection loop, we relied on previous research regarding decision-making models, vigilance and detection loops, and models of expert decision-making (Boyd, 1987; Klein, 1998; Klein, Calderwood & Clinton-Cirocco, 1986; Mueller, 2009; Mueller & Weidemann, 2008). The model allows us to make predictions about Soldiers' performance as they gain competency and develop toward expert stages. According to the model, proficient Soldiers should be better able to monitor and search their environment in order to detect changes or anomalies.

One goal of this research was to identify differences in experienced and novice threat detection processes, thus the model provided a guideline for identifying metrics of expertise. Each step in the loop is associated with measureable behaviors that indicate the influence of experience on threat detection. To determine how behaviors contribute to threat detection, it is possible to measure these behaviors in exercises or laboratory settings. As experience increases, Soldiers may improve their ability to perform many of the component skills required to detect threats.

This research examined several of the behaviors identified in this model to detect the presence of these skills in more experienced Soldiers and to create training to improve threat detection skills in less experienced Soldiers. Given this model, we expected to find a difference in the skills of more experienced Soldiers compared to the skills of less experienced Soldiers. For example, experienced Soldiers should more readily identify threat versus non-threat features compared to less experienced Soldiers who may not have the experience and subsequent mental models to understand which features indicate a relevant threat. It is also likely that experienced Soldiers would make comments about these features that differ from comments made by non-deployed Soldiers. Soldiers with little experience may not be proficient at identifying cues or features in the environment that are relevant to detecting threats. They may also have difficulty distinguishing between cues that are relevant and those that are irrelevant or typically do not indicate a threat. Because they lack the relevant experience base, they may not be able to explain why certain cues are threats in specific contexts or hypothesize about what the enemy might do in similar circumstances. Experienced Soldiers should be able to reason through why features indicate a threat and describe hypothetical actions and outcomes.

Expertise Development

The observations of police officers in Phase I indicated that the less experienced officer tended to respond readily to many potential threats without discriminating between cues based on threat severity or likelihood. Meanwhile, more experienced officers seemed to evaluate possible threats with little deliberation and judge threat severity by weighing the probability of effective outcomes. Research shows that, compared to their novice counterparts, domain experts are better able to perceive and process information, recognize pertinent cues, and match those present cues to previous experiences in a manner that facilitates successful action (Ericsson & Charness, 1994; Goodrich, Sterling, & Boer, 2000). While the initial research phases indicated that experience and knowledge influence and facilitate the threat detection process, that research did not compare the cognitive skills of Soldiers with varying degrees of threat detection experience. In order to create effective training that leveraged Soldiers' experiences, it was important to determine if differences in cognitive and perceptual strategies and skills exist.

A training program that improves the cognitive skills used to detect threats should incorporate exercises that promote novice advancement toward expert performance levels. Dreyfus and Dreyfus (1986) proposed a five-stage model of skill acquisition to describe how decision-making changes as experience increases. At the novice stage of this model, decision makers recognize objective facts about situations and apply “context-free” rules to the situation. As decision makers progress through the advanced beginner and competent stages, they begin to recognize meaningful elements of specific situations and begin to incorporate those elements into decisions. As expertise develops through the proficient stage, decision makers begin to perceive situations as a whole, rules become less important, and decision makers become more flexible and react faster to incoming information. In the final or expert stage, decision makers intuitively recognize situations and match them to previous experiences. They use mental simulation to predict events and outcomes of actions and they deal with uncertainty by story-building and actively seeking information (Dreyfus & Dreyfus, 1986; Ross, Phillips, Klein, & Cohn, 2005). This model provides a template for how threat detection proficiency may change as Soldiers acquire experience. The behaviors predicted by the threat detection loop (presented in Figure 1) are characteristic of decision makers in the proficient and expert stages of the Dreyfus and Dreyfus model.

Previous research examining assessments made by novice and experienced police officers of a traffic stop video provided insight into the differences in perceptions and interpretations of a threatening event (Zimmerman, 2008). In that research, police officers viewed a video taken from a patrol car dashboard camera in three segments. At the end of each segment, they provided their assessment of the situation including cues that indicated a threat, interpretations of the events, and courses of actions they would take. Novice and experienced police officers tended to focus on the same types of cues, but differed in how they elaborated on their observations. Consistent with prior research (Klein, Phillips, Battaglia, Wiggins, & Ross, 2002; Phillips, Klein, & Sieck, 2004), experienced police officers provided descriptions of the event that were more elaborate, provided and interpreted more cues, and made more interpretations and predictions about what would occur. This finding is similar to previous research showing that less and more experienced decision makers use similar sensemaking strategies, but experts show a deeper understanding of the situation and provide richer explanations (Klein et al., 2002). Novice officers tended to focus on procedural issues, such as officer safety, and they rarely tried to ascribe meaning to threatening behaviors or interpret the scene in multiple ways. Experienced officers tended to consider the context surrounding the situation and make interpretations based on their prior knowledge of officer, driver, and criminal behavior. They weighed the relevance and importance of cues within the context of the current situation whereas novice police officers identified threat cues and based their probable actions on the cues without necessarily considering the context.

In Zimmerman, et al., (In Preparation), Soldiers with combat experience in the OE emphasized the importance of experience when searching environments to detect threats. They reported threat search processes that focused on procedural tasks, such as using intelligence and typical information gathering techniques, but, unlike the novice police officers, they did not tend to focus on Soldier safety. Instead, they provided examples from their experiences of techniques they use to search for threat cues, such as noticing atypical threat indicators and leveraging the opinions of other Soldiers. Soldiers were able to verbalize the learning process that occurred during their deployment, particularly how they learned to sort and filter information and distinguish between threats and non-threats. Their comments also indicated that they could process threat cues, predict the consequences of those cues, and take preventative actions. They also recognized that some threat cues were too prevalent or random to spend much energy detecting, such as trash along the side of the road. Soldiers' comments indicated that they consider their surroundings when interpreting threat cues, for instance, by noticing trends and changes and reassessing situations given the new context. The Soldiers in Phase III viewed photos and not only provided comments about the threat cues present but also were able to present detailed hypothetical scenarios based on the scenes in the photos and discuss plausible actions they would take. These comments are characteristic of experience-based processing and interpretations of situations.

Experiment

Overview

Based on the expert threat detection model (Figure 1) and the results from the previous experiments, subsets of the stimuli were piloted during the Phase III research (Zimmerman, et al., In Preparation). These stimuli provided an opportunity to identify useful targets for use in the training exemplar development. The current research added a change detection exercise to investigate differences in the ability to detect changes based on experience and to understand the extent that Soldiers use change detection to identify threats. During the initial phases of this research, Soldiers indicated that detecting changes is an important component of threat detection, as represented in the threat detection loop.

Soldiers at Fort Hood, TX, engaged in three computer exercises: a prioritized threat search, dynamic threat detection, and change detection. Upon completion of those exercises, the Soldiers viewed photos during interviews and identified threat cues, discussed these cues and areas of concern, and provided their interpretation of the scenes.

Method

Participants.

Forty-seven U.S. Army Soldiers participated in computer exercises and interviews. Twenty Soldiers were NCOs (Sergeant; SGT to Master Sergeant; MSG), one was an Officer (First Lieutenant; 1LT), and 26 were enlisted (Private; Private to Corporal; CPL/ Specialist; SPC). All Soldiers were male. Table 1 lists the average age, mean time in service, and the mean number of times deployed for each group.

Table 1

Junior enlisted and NCO mean age (range), time in service (range), and number of deployments

Rank	Mean Age	Mean Time in Service	% Deployed
Junior Enlisted	23 (18-37)	27 mo. (4-72)	54%
NCO/Officer	29 (23-44)	103 mo. (31-192)	95%

Soldiers reported zero to four deployments. Thirty-four Soldiers reported deploying at least once. Of those who deployed, 83% were combat arms. Table 2 lists the number of Soldiers in each rank by the number of times they have deployed.

Table 2

Soldier rank and number of deployments

Rank	Total	Number of Deployments 0	1	2	3	4
Private	2	1	1			
PV2	3	3				
PFC	11	8	3			
CPL/SPC	10		7	3		
SGT	1		1			
SSG	11	1	1	6	3	
SFC	7			3	3	1
MSG/1SG	1				1	
1LT	1		1			
Total	47	13	14	12	7	1

The most common military occupational specialty (MOS) reported by Soldiers was Infantryman (11B), with 15 deployed and 2 non-deployed Soldiers reporting this MOS (Table 3). Only one Soldier reported a current MOS different from the MOS held while deployed. This Soldier reported that his current MOS was Armor Officer (19A), however, his MOS while deployed was a Motor Transport Operator (88M).

Table 3

Soldier MOS and deployment status

MOS	Deployed Yes	No
11B Infantryman	15	2
12B Combat Engineer	5	2
13F Field Artillery Forward Observer	3	
19A Armor Officer	1	
19D Armor Scout	2	1
19K M-1 Crewman	4	2
25N Nodal Network Operator (Signal)	1	
25Q Multichannel Transmission Systems Operator-Maintainer		3
74D Chemical, Biological, Radiological, and Nuclear Warfare Specialist		1
91A M-1 Tank Mechanic		1
91M M-2/3 Bradley Mechanic	1	1
92F Petroleum Supply Specialist	2	
Total	34	13

Deployed Soldiers rated how often they went 'outside the wire,' or how often they traveled off their Forward Operating Base (FOB) or similar location, on a scale from 1 (rarely or never) to 4 (almost every day). Twenty-seven Soldiers reported going outside the FOB almost every day (M = 3.65, SD = 0.77).

Materials.

Computer-controlled Questionnaire. Materials similar to those used in the previous experiments were used for the current research (see Zimmerman et al., Appendix A). These included a computer-controlled demographic and experience questionnaire that contained a subset of the questions asked in the previous research and additional questions relevant to the current research (Appendix A). Special-purpose software using the Psychology Experiment Building Language (PEBL) 0.09 computer experimentation system controlled the computer exercises (Mueller, 2009). The participant section (above) presents the relevant data from this questionnaire.

Computer-controlled Imagery Analysis. The three computer-controlled threat detection exercises presented photos selected from a set of 48 images approved for public release. These images were retrieved from three main sources, www.DefenseImagery.mil, www.Flickr.com, and www.defense.gov. Findings from the previous experiments guided the photo selection process for the final set of 40 images. These images were divided into four groups of 10 and each group of 10 images was assigned to one of four conditions: time-unlimited prioritized threat search, time-limited prioritized threat search, single-task threat detection, and dual-task threat detection. Four counterbalanced conditions were devised using a Latin square design and participants were assigned to each counterbalanced condition based on the order in which they participated in the data collection.

Twelve additional images were selected as stimuli for the change detection exercise. Image-editing software enabled the creation of two versions of each image by seamlessly adding or removing specific features from the images. Changes included both threat-relevant features (brickwork, trash, people, vehicles, etc.), and threat-irrelevant features (the length of poles, ornamental architecture detail, etc.). Soldiers viewed one version of each of the change-detection images during the initial prioritized threat search exercise and tried to detect changes on the second version of each image at the end of the sessions.

Interview Protocol. The interviews focused on gathering information about the causal reasoning used to make threat detection choices during the computer exercise. The set of photos used in the computer exercises and previous research were used to gather information about Soldier thought processes and reasoning while detecting threats.

Procedure.

The research consisted of two main parts: a computer-controlled exercise and a semi-structured interview. At the start of each session, following administration of privacy act and informed consent protocols, Soldiers read a description of their exercises and were told that they were there to provide information about their threat detection experiences and to identify common threat detection situations, indicators, and challenges in the OE. Soldiers then completed the computer exercises at their own pace which typically took 45 minutes to complete.

Following the demographic questions, Soldiers completed five consecutive computerized exercises developed to measure attention, search, reasoning, and prioritization strategies for threat detection. The first two exercises involved a resource-limited threat search process referred to as the *prioritized threat search*. The second two exercises involved *dynamic threat detection* in which Soldiers engaged in a stimulus detection exercise with distracters. Finally, in the *change detection exercise* Soldiers viewed changed imagery which they first saw during the prioritized threat search exercise and they annotated any changes observed.

Prioritized threat search. The first two computer-controlled exercises following the demographic questionnaire required Soldiers to search an image for potential threat targets using a virtual "scope" (Figure 2). Each image contained approximately 10 possible target locations. The annotations provided by Soldiers in the previous experiments formed the basis for these target locations. The click locations from previous experiments were not suitable for direct use because they generally contained too many targets, thus a small number of reasonable and distinct target locations was selected based on visual examination of the annotated imagery. When Soldiers clicked the 100-pixel diameter circular scope on one of the target locations, a red dot (identified target) would display with a 65% probability rate of detection. This probability allowed participants to conduct repeated searches of the image in locations they suspected of containing a target. For each image, Soldiers could make a maximum of 10 search clicks. The first search exercise had no time limit and contained 18 images. The second search exercise also had 18 images. Soldiers had a maximum of one second per click to search each photo (if they did not use the click after one second it would become unavailable) and after each click the timer decremented to the next even remaining second. This scheme encouraged Soldiers to search steadily throughout the 10second time period rather than click haphazardly when time was about to elapse. Each condition in the prioritized threat search exercise contained 12 images from the main set of counterbalanced photos and an additional six images used in the first part of the change detection exercise. Soldiers did not know that the change-detection images would appear again later.

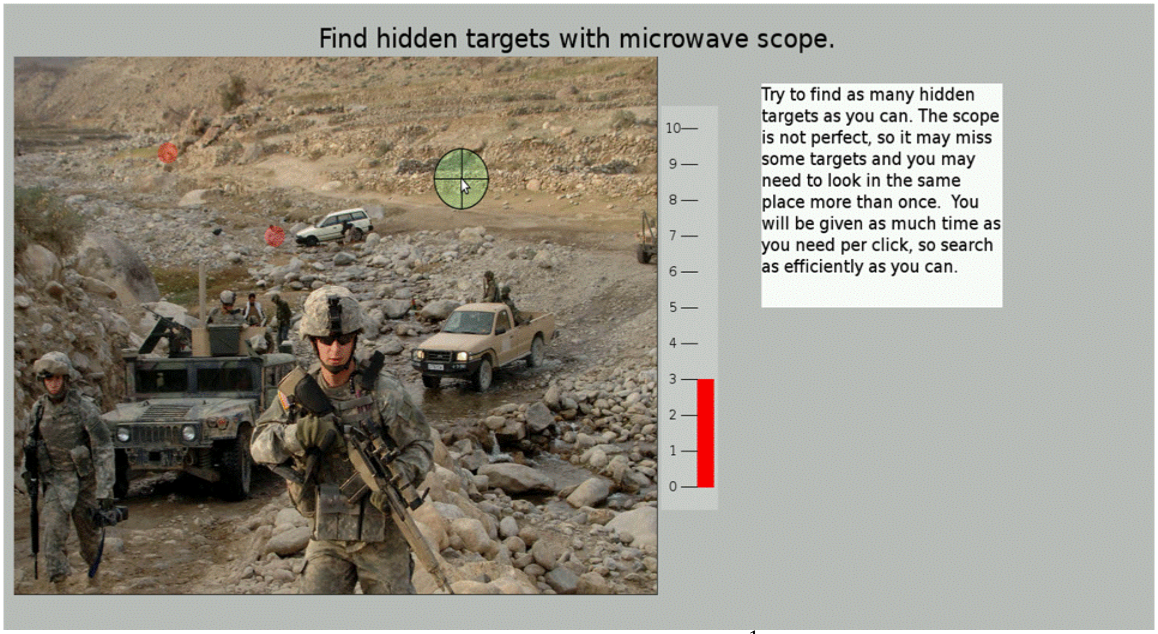

Figure 2. Screenshot of prioritized threat search exercise.[1]

Dynamic threat detection. The design of the cued threat detection exercise allowed experienced Soldiers to use their background knowledge of threats to guide their visual attention. On each trial, the screen displayed an image overlaid with 75 transparent grey dots (noise) distributed randomly, but consistently over the image.[2] These dots vibrated and obscured the image. These grey dots obscured the appearance of the target dot and required Soldiers to maintain constant vigilance in order to detect the target among the field of dots. The target dot was identical to the noise except that it had a light orange rim around the circle. The Soldiers' task was to click the mouse button as soon as a target was detected which revealed a mouse cursor. Once the cursor appeared, they could indicate the location of the target. Each image presented seven targets in threat-consistent locations and three targets in threat-inconsistent locations. The threat-consistent locations were determined by examining responses from previous research with the same or similar imagery.

[1] The red bar on the right of image shows remaining search clicks available. Found targets are displayed as transparent red dots and the virtual threat scope as a transparent green overlay.

[2] Each transparent dot had a radius of 12 pixels. Throughout the trial, the location of these dots was jittered with a bivariate uniform distribution of five pixels. The dot locations updated approximately every 100 milliseconds. A target dot appeared in the dot field at random delays of between 5 and 10 seconds.

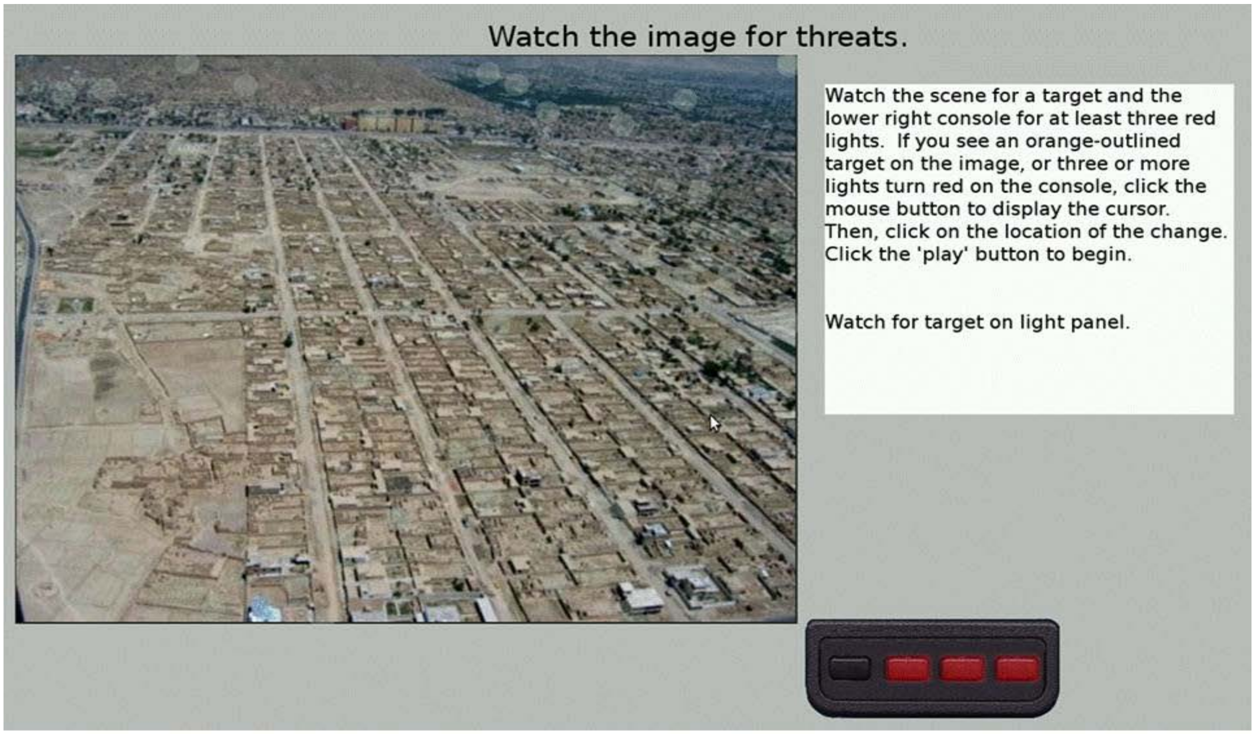

Figure 3. Screenshot of dynamic threat detection exercise.[3]

A second round of the dynamic threat detection exercise required simultaneous monitoring of changes occurring on a secondary light monitor. The light monitor was located in the lower right section of the image and had four virtual LED lights that flashed either blue or red (Figure 3). On each cycle, three lights would illuminate, typically, one would be red and two would be blue. When the target appeared, three of the four lights would flash red, but would still update on the same cycle so the three red lights would appear for the same length of time as the other combinations of blue and red lights. Soldiers needed to monitor both the photo for the target (grey dot with orange outline) and the light display for three red lights. When they detected the three red lights, they would click on the screen outside the photo rather than on the location of the target location in the photo. The purpose of this manipulation was to assess the degree that threat detection experience affected performance when simultaneously performing multiple tasks. Research on novice and expert performance shows that novices typically must consciously attend to the task they are performing while experts do not need to apply as much conscious thought and attention (Beilock & Carr, 2004; Beilock, Wierenga, & Carr, 2002; Shiffrin & Schneider, 1977). As a result, experts should be able to devote more attention to the dual task without a performance decrement while novices should perform poorly under dual task conditions.

Change detection. The final computer exercise involved “change detection,” in which Soldiers viewed altered versions of 12 images they had seen during the prioritized threat search exercise. They viewed half of the images in the untimed version of the exercise and the other half in the timed version with the photos counterbalanced across Soldiers. In addition, the first

[3] At this point, three of the secondary monitor lights were illuminated.

version of the change photos shown appeared at random so that half the Soldiers saw the original image during the exercise, whereas the other half saw the altered version. The changed images were intermixed randomly with the normal threat search imagery, thus Soldiers had no indication that these images would later appear as a test of their change detection skill. At test, Soldiers were told that several things were different about the image compared to the first time they had seen it (Figure 4). They used the mouse to indicate a location and gave a brief annotation describing what they believed had changed.

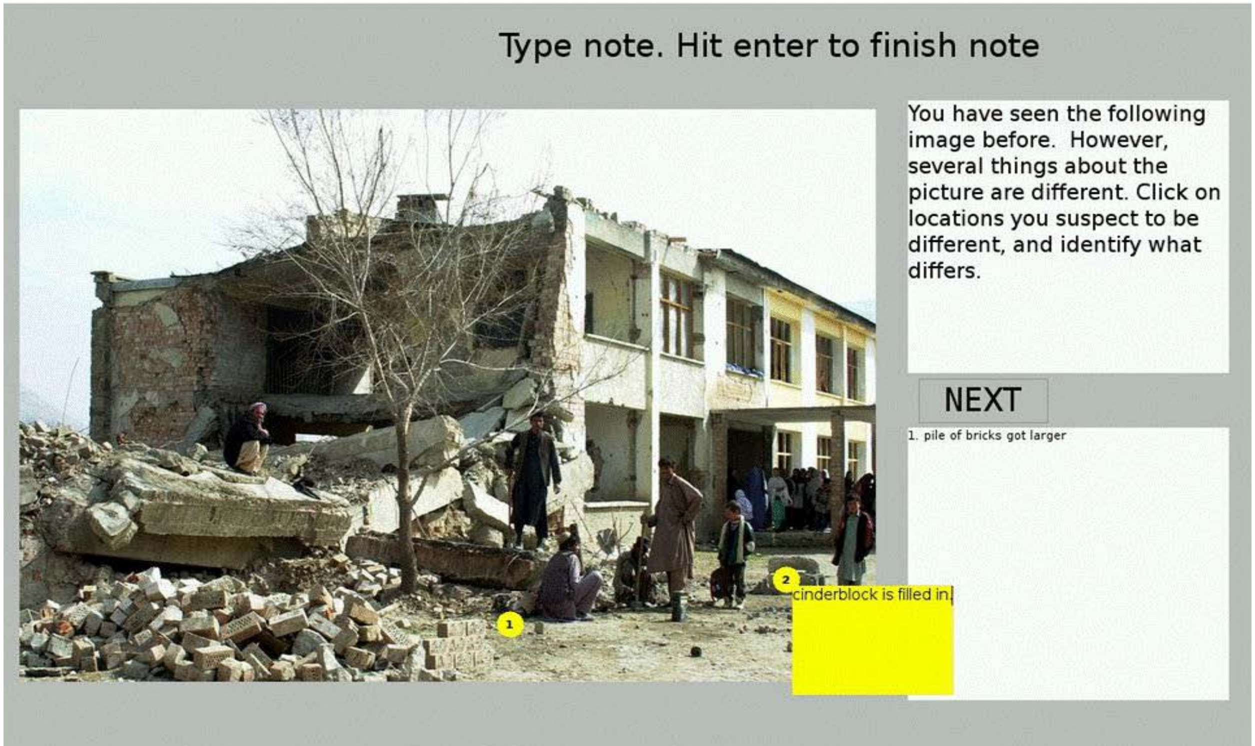

Figure 4. Screenshot of change detection exercise.[4]

Interviews. After the computer exercise, the research staff interviewed Soldiers about their threat detection experiences. The interviews lasted approximately 30 minutes. Soldiers were instructed to look through a set of images (that had been used in the computer tests) and select one or more that reminded them of a situation they had experienced (in training and/or operational environments). They identified and described the threats in each photo and provided explanations about the threats they deemed important. They discussed the threat-related events that might occur in each photo and discussed possible threat scenarios. Finally, Soldiers provided feedback about the computerized exercises and made suggestions for computer-based training exemplar development. During the debriefing, Soldiers could ask questions and provide feedback about the experiment and the project. They received contact information for mental health assistance if discussion of their experiences brought up any negative feelings or memories.

[4] Participants indicated locations of changes and annotated what they believed the change was.

Analysis.

Threat Detection Exercises. The R statistical computing platform Version 2.10.1 (R Core Development Team, 2009)[5] was used to analyze the data from the computerized exercises. R provided a number of useful add-on modules that enabled image analysis and display. In addition, for the prioritized threat search exercise, R created images that overlaid transparent red indicators on top of the original stimuli to indicate the clicked locations of all participants (Appendix B).

Interviews. To conduct the interview analysis, interview recordings were transcribed. The Soldiers' comments were sorted into pre-determined categories, which had been developed during the previous phases of research (Zimmerman et al., In Preparation). These categories include types of threats, threat cues, strategies for threat detection, threat detection tasks, skills, challenges, and training (Table 4). Because Soldiers with different amounts of experience commented on the same photos, we compared comments made by less and more experienced Soldiers in each of these categories and compared comments made by multiple Soldiers to the same photos. Interviews were coded line by line to identify potentially important pieces of data. We compiled these specific comments according to these categories and kept the coder blind to each Soldier's characteristics. After comments were sorted into each broad category, specific comments were separated out according to finer distinctions. For example, within the category threat cues, comments could be those related to behavioral, person, or environmental cues.

After all comments were coded according to these categories, we began to identify elements in the 5-Stage Skill Acquisition Model (Dreyfus & Dreyfus, 1986). Each comment was represented at a stage in the model so we could ascertain their level of skill development. At that point, we identified Soldiers' experience levels and identified comments as belonging to inexperienced Soldiers (no deployments) or experienced Soldiers (Soldiers with one deployment, and Soldiers who had between two and four deployments). The number of Soldiers who made comments in each of the high-level categories were counted and separated according to experience level. After that, comments were separated within each category according to experience level so that similarities and differences could be examined within the level of experience.

In order to identify comments as they related to the threat detection model, we relied on the same initial coding scheme, although this time solely focusing on the experienced Soldiers. We then identified each comment according to the threat detection model and sorted the comments according to each part of the model.

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[5] R is a commonly used statistical computing tool available for use on all common computing platforms, http://www.r-project.org/

Table 4

Interview data categories

Interview Data Classification	High-level Categories
Types of Threats	Enemy activity, enemy tactics, activity in the environment, troop activity, crowd behavior
Threat Cues	Behavioral cues, environmental cues, physical cues (such as wires, garbage), patterns of cues
Strategies for Threat Detection	Tactics, information gathering, spot cues, spot trends, ask what-if questions while assessing situations
Threat Detection Tasks	Scan environment, question subjects, active evidence search, observe situations and environments
Threat Detection Skills	Think like the enemy, prioritize information, aggregate information, form mental picture of situation, regularly ask what-if questions
Challenges in Detecting Threats	Noticing cues, noticing patterns, enemy Tactics, Techniques, and Procedures (TTP), information reliability, night operations
Solutions for Threat Detection Training/Preparation	Scenario-based training, train consequences, use Iraqi/Afghan role-players/environments, think like the enemy, real-world experience, train with what-if questions

Results and Discussion

Threat Detection Exercises.

Prioritized Threat Search. The prioritized threat search exercise measured performance with and without time pressure. The number of threats discovered by Soldiers provided a metric of performance in both conditions. Soldiers found targets in an average of 2.14 clicks while under time pressure and 2.32 clicks when not under time pressure. A Welch 2-sample t-test determined these to be significantly different [$t(1374) = 2.05$, $p < .05$, *Cohen's d* $= 0.11$], showing that time pressure reliably reduced the number of targets found. Another way to judge search accuracy was to compare each Soldier's click to the other Soldiers' click locations. For each click, the number of clicks made by other Soldiers that were within the scope radius of the specified location was counted. This value ranged from 0 to 77 with a mean of 18.4. The number of clicks within the scope radius indicated whether the location was in a sparse or dense region. Sparse regions contained fewer than 10 close clicks indicating few Soldiers clicked in those regions while dense regions contained 10 or more close clicks indicating many Soldiers clicked in those regions. Approximately 65% of the click locations were in dense regions. For each Soldier, the number of clicks made in dense regions with and without time pressures were

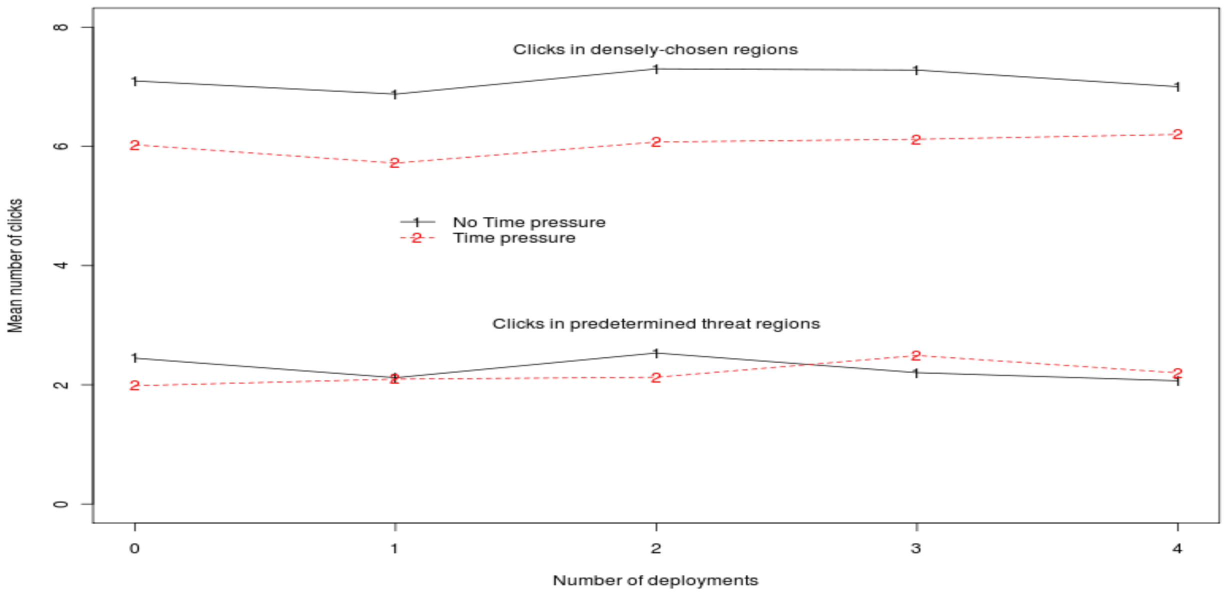

Figure 5. Two measures of search accuracy, plotted by time pressure and experience.

calculated. Under time pressure, Soldiers made 5.96 dense clicks on average. Under no time pressure, they made an average of 7.1 dense clicks. This difference was statistically significant and indicated a medium-sized effect, $t(1351) = 8.90$, $p < .01$, *Cohen's d* = .48.[6] In contrast, there was no reliable difference between the mean number of sparse clicks in the two conditions without time pressure ($M = 2.90$ versus with time pressure ($M = 3.07$), $t\ (1363) = -1.4$, $p = .17$, *Cohen's d* = .07).

Analysis of Soldier experience focused on the number of deployments. Figure 5 depicts the relationship between experience and time pressure for clicks in the predetermined threat regions and clicks in the dense regions. The results show very little difference across experience levels, but highlight the impact that time pressure has on performance. One explanation for the relatively larger impact of time pressure on clicks in dense regions is that when under time pressure Soldiers missed opportunities to search the photo as time elapsed. Similar results were found when using other measures of performance such as the number of threats identified. Click density measures were also used; those measures incorporated experience or how well an individual matched the group. Click density is the most appropriate measure because there were

[6] A *Cohen's d* of .48 indicates a medium effect size. Effect sizes indicate the strength of the relationship between two means. When calculating *Cohen's d,* a small effect is around .2, medium effect around .5, and large effect .8.

no objectively correct threats in the image and thus examining a sparse location could be considered incorrect. Random clicking on an image suggests an inability to recognize and indicate relevant threats whereas condensed clicking suggests a focused search of an image for certain cues.

To determine if the effects of experience on search accuracy were reliable, a linear regression was computed with linear predictors for number of deployments, time pressure, and a deployment x time-pressure interaction. When analyzing the number of clicks in which Soldiers found a target, the number of deployments was unrelated to performance, but time pressure and the time pressure x deployments interaction were both statistically significant (Table 5). This interaction shows that the deployment slope is slightly positive (.048 clicks/deployment) when under time pressure, but slightly negative (-.118 clicks/deployment) when not under time pressure. This result indicates that Soldiers with more deployments performed slightly better when under time pressure versus when not under time pressure. However, the results are quite small overall. Most Soldiers had fewer than two deployments so the effect should be interpreted with caution.

Table 5

Linear regression of clicks on predetermined targets by deployments and time pressure

Predictor	Estimate	S.E.	t	Pr(>|t|)
Intercept	2.362	0.093	25.278	< .001
Deployments	-0.035	0.053	-0.655	0.512
Time pressure	-0.397	0.132	-3.002	0.003
Deployments x pressure	0.166	0.075	2.194	0.028

Residual standard error: 1.574 on 1372 degrees of freedom
Multiple R-squared: 0.007698, Adjusted R-squared: 0.005529
F-statistic: 3.548 on 3 and 1372 df, p-value: 0.01405

The analysis of clicks in dense regions showed a reliable positive relationship between the number of deployments and time pressure, but the impact of time pressure was quite large (by more than one click). Table 6 shows the linear regression results of the model which indicate only a statistically significant effect of time pressure. Together, these results indicate that time pressure had an impact on performance. The data also suggest this impact might be larger for novices and experience reduced or even reversed this effect. Future research could investigate this effect to understand whether and why time pressure may have potentially less influence on experienced Soldiers. For instance, more experienced Soldiers are more likely able to sift through relevant and irrelevant information even in time-pressured situations.

Table 6

Linear regression of density by deployments and time pressure

Predictor	Estimate	S.E.	t	Pr(>|t|)
Intercept	6.999	0.141	49.64	< .001
Deployments	0.078	0.080	0.97	0.335
Time pressure	-1.117	0.199	-5.60	< .001
Deployments x pressure	-0.018	0.114	-0.16	0.874

Residual standard error: 2.375 on 1372 degrees of freedom
Multiple R-squared: 0.05566, Adjusted R-squared: 0.05359
F-statistic: 26.95 on 3 and 1372 df, p-value: < 2.2e-16

Dynamic threat detection. The threat search exercise involved searching for targets that appeared in a dynamic field of transparent dots that jittered throughout the search (Figure 3). Soldiers responded correctly when they clicked the mouse while the target appeared on the screen and then indicated the location of the target within 100 pixels of its actual location. While 100-pixel criterion is somewhat arbitrary, Soldiers were able to meet this criterion the majority of the time. Out of 5,734 total trials in which a target appeared on the image, Soldiers clicked the mouse to indicate the target was present 3,107 times and 2,598 of these times Soldiers indicated the target location within 100 pixels. The number of correct and precise trials only varied from 2,584 to 2,601 when the criterion varied from 50 to 150 pixels, indicating the 100-pixel criterion was robust.

When analyzing the proportion of correct (clicked mouse when saw target) and precise (accurately indicated location of target) trials in the single and dual-task search exercises, the results showed an overall accuracy rate of about 50%. Fewer than half the threat-irrelevant targets detected and greater than half the threat-relevant targets detected (Table 7). Dual task trials had higher mean accuracy than single-task trials; however, this finding may stem from practice effects because the single task was always completed first and the dual-task second. We intentionally did not counterbalance the order of the single and dual task conditions because the dual task condition would have been too difficult and the secondary task did not require Soldiers to have familiarity with the primary task. The photos were different in the single and dual tasks.

Table 7

Mean accuracy and time for the threat search exercise

Condition	Irrelevant	Relevant	Monitor
	Accuracy		
Single	0.446 (.026)*	0.585 (.028)	NA
Dual	0.513 (.037)	0.629 (.042)	0.373 (.057)
	Time to respond (ms)		
Single	4556 (91)	4134 (85)	NA
Dual	4513 (106)	4064 (120)	4668 (174)

**Note*. Estimate of standard error in parentheses.

To assess whether the differences between conditions were statistically reliable, a model predicting log (accuracy) based on Condition (single-dual), Relevance, a Condition x Relevance interaction, and participant enabled within-subject comparisons. We analyzed log (accuracy) because residuals from the raw accuracy scores were skewed and a normal distribution better described the residuals from a log (accuracy) model as assumed by the linear regression. This procedure excluded the trials in which the target appeared as the three red monitor lights (as they were neither relevant nor irrelevant) although the other trials from the dual task condition were included. Results of an Analysis of Variance (ANOVA) on this model indicated a statistically significant effect of threat relevance, $F(1,45) = 92$, $p < .001$, $\eta^2 = .67$, and no reliable effect of either single versus dual task condition, $F(1,45) = 2.1$, $p = .15$, $\eta^2 = .044$, nor was there a reliable interaction, $F(1,45) = .65$, p = .42, $\eta^2 = .014$.

A second performance measure analyzed was Soldier time-to-respond when they detected a target. Similar to accuracy, Soldiers responded faster to targets in relevant locations than to targets in irrelevant locations. Because response time was positively skewed, we performed an ANOVA on log (reaction time) which again revealed a reliable effect of relevance on response time, $F(1,44) = 6.3$, p =.016, $\eta^2 = .12$, a reliable effect of the single and dual task conditions, $F(1,44) = 23.7$, $p < .001$, $\eta^2 = .345$, and no reliable interaction, $F(1,43) = .04$, $p = .82$, $\eta^2 = .001$.

Across the two primary measures (accuracy and time-to-respond), there were differences between threat-relevant and threat-irrelevant target locations which is promising because it suggests that measuring such differences in a future training system may help provide metrics about skill level that can be used for assessment and/or feedback. The faster response time in the dual-task condition compared to single-task condition is counterintuitive. This finding may be a practice effect or may stem from an overall higher level of arousal induced by the more difficult dual-task situation. However, the reliable impact of threat relevance indicates that Soldiers were typically able to infer threat-relevant locations and focus their attention in those locations which degraded their performance on threat-irrelevant trials.

To assess whether Soldiers with more experience differed in their ability to attend to threat-relevant locations, a threat bias score was calculated for each Soldier by dividing their mean response time by their mean accuracy. The threat bias score assessed the extent to which detection is biased toward threat-relevant regions of visual space. A ratio value of 1.0 would indicate equal performance for both types of targets, values less that 1.0 would indicate a bias toward threat-relevant locations (i.e., they were identified faster and more often). The natural logarithm of these values was used to perform a linear regression analysis that compared the log ratio to number of deployments reported by Soldiers[7]. A negative threat bias score indicated that Soldiers were biased toward detecting and identifying targets in threat-relevant regions. Such a bias is likely to be adaptive and indicates Soldiers are using their limited attentional resources to monitor the most likely targets, but also indicates that they may miss seeing threats that appear in unlikely places. The slope (*beta* = -.31 log-RT units per deployment, $t(44) = -.39$, $p = .69$) and the intercept (-.015) were not significant. This indicates that all Soldiers had a tendency to identify targets in threat-relevant locations regardless of the number of deployments (Figure 6).

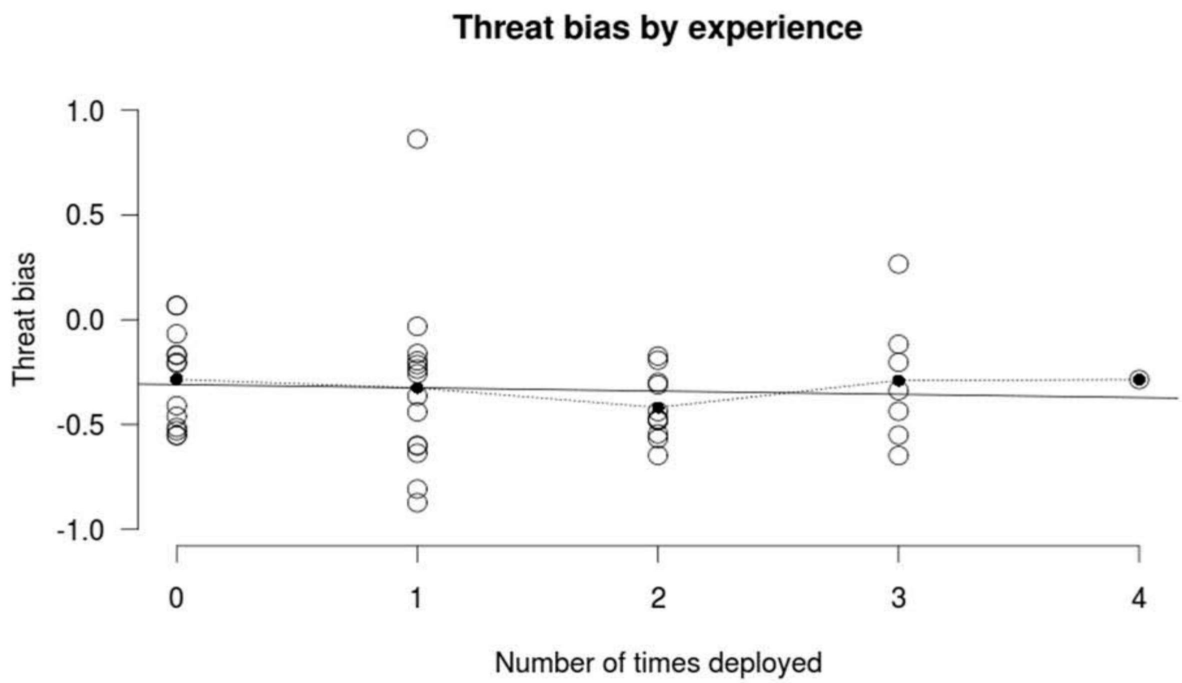

Figure 6. Relationship between bias to detect threat-relevant vs. threat-irrelevant locations and number of times deployed.

Change Detection. To assess change detection ability, each base image was coded according to its critical change locations. Coding of the changes in each image indicated the

[7] The natural log transformation was used to correct for truncated range between 0 and 1 in cases where mean accuracy exceeded mean response time.

presence, absence, or the change of a feature. In addition, coding differentiated each change as threat relevant or threat irrelevant. The image set contained 62 coded changes and although each Soldier saw all 62 images, they responded to only half the images totaling 31 changes per Soldier. This coding revealed 27 (44%) changes as irrelevant and 35 changes (56%) as relevant.

Results showed several important trends. Across all Soldiers, they annotated 355 targets but 281, or 79% of these targets did not involve an actual change between the two images. These 281 false alarms were not coded as threat relevant or irrelevant. Of the remaining 74 identified targets, 71 were in threat-relevant locations, providing evidence that participants noticed changes related to threats (Table 8). Furthermore, participants were more likely to identify a target when a feature was absent in the first viewing but present in the second viewing (56 trials) versus when the target was present in the first viewing, but absent in the second (15 trials).

Table 8

Distribution of target identifications in change detection exercise

		Threat status	
	Uncoded	Irrelevant	Relevant
Feature present	0	3	53
Feature absent	0	0	15
Feature change	0	0	3
No change	281	0	0

The overall high proportion of false alarms could be evidence that change detection skill was poor and may even indicate random guessing. However, the proportion of targets actually found when Soldiers had no warning they should look for changes, indicates an existing ability to detect change. Although only about 20% of the responses were for actual changes Soldiers selected about 3% of the image areas as the change zones (ranging from 0.37% to 12.7% across images). Thus, Soldiers were about 6.7 times more likely to indicate actual changes than if they had been responding by chance. To assess whether performance differed reliably from chance, mean accuracy rates (the number change targets identified relative to the total number of attempts) were compared to the proportion expected by chance. Forty-six Soldiers took part in the exercise, but two provided no responses. Across the remaining 44 Soldiers, the mean proportion of attempts that identified a change target was .233 with a 99% confidence interval between .14 and .32 (three Soldiers did not complete the change exercise because of time restrictions). The chance proportion of .03 identified change targets lies far outside the region, $t(42) = 5.9$, $p < .0001$, Cohen's $d = 0.90$.

Because we were interested in how change detection occurs in an applied setting (as opposed to in a laboratory), we made use of what is commonly referred to as the incidental approach (Levin & Simons, 1997). In these situations, participants are not informed that a change or difference will occur and they are often asked to perform an intermediary task as their primary task. In Rensink's review (2002, p. 257) he notes, "The degree of [change] blindness encountered is generally much higher than that found using intentional approaches. However, some ability to detect change remains." The results of the change detection exercise used in this research support that idea. Based on the results, Soldiers may be considered to have had a lower response threshold or a high false alarm rate. However, when they indicated changes that were indeed present, they were most likely at threat-relevant locations. Given the severe consequences of not detecting threat-relevant changes in the operational environment, adopting a lower threshold is an adaptive strategy.

Interviews: Threat Detection Model.

The analysis presented in this section aimed to link the comments from Soldiers with deployment experience to the Threat Detection Model proposed by Zimmerman et al., (In Preparation). These comments provide select examples of behaviors that map onto the loop (see Figure 1). The next section provided examples specifically relevant to expertise development.

Experienced Soldiers often discussed threat detection exercises that related to their cognitive and perceptual processes such as encoding details about the situation (see Threat Detection Loop, Figure 1, box a). For example, Soldiers made the following comments:

- "Just keep an eye out…to keep an eye out for a vehicle and right in here where they're sitting."
- "You have to focus on everything, pay attention to what they're wearing."
- "So, I just watched people…I know, okay this time of day, these people are going out and this time of day, they're coming back."

Soldiers also made comments about their information gathering processes that demonstrate their need to balance making decisions about a threat with the need to gather information (f).

- "It should be with the local people; they (will) give away everything…they'll come and tell you."
- "Presence patrols; we'd do a lot of them. And a lot of times we'd go to each shop and talk to people in there and ask them if they noticed anything weird in the area."

Soldiers with experience often described the challenges related to properly classifying threat cues and threat irrelevant cues (b) and their ability to detect changes in an environment (g). They reported:

- "It's dirt and gravel which is not cool because it's too easy to mess with dirt and gravel and make it look the same. Pavement is a little bit easier to notice differences."
- "I really don't like looking for IEDs: too many places to put it, to hide it, hard to find, not enough manpower."
- "Really, no matter how you looked at it, you could look at almost anyone and decide if you think they're suspicious."

- "I mean they changed their tactics every day and every time we changed ours, they'd change theirs. So it's hard to…one day it could be a coke can sitting right there and the next day it could be a tire. You just never know."

Soldiers also indicated that they often relied on prior experience and knowledge to determine their search strategies and this, in turn, influenced their ability to detect threats. An example statement provides illustration of incorporating prior experiences into decisions (d):

- "You'll see a lot of the areas that they've used before. And it's a big give away, like they'll use telephone poles as markers and they'll use light poles, they'll use trees, intersections."

Interviews: Expertise Development.

This section provides findings from the interviews that represent typical responses from Soldiers who have never deployed, those who have deployed once, and those who have deployed two to four times. The purpose of this analysis was to identify differences in causal reasoning skills between less and more experienced Soldiers as they identified and discussed possible threats in photographs depicting real-world situations. The results contain information given by Soldiers in response to the photographs that pertain to the high-level categories (Table 9). Soldiers in all three groups (0, 1, or 2-4 deployments) were able to identify or discuss types of threats, threat cues, and threat detection exercises. Soldiers with deployment experience more often discussed strategies for threat detection, threat detection skills, challenges in detecting threats, and solutions. The interview analyses explored the content of these differences by comparing comments made by less and more experienced Soldiers in each category.

Table 9

Number of Soldiers who made comments in each interview data category

	Types of Threats	Threat Cues	Strategies for Threat Detection	Threat Detection Tasks	Threat Detection Skills	Challenges in Detecting Threats	Solutions
Never Deployed *N = 13	13	13	8	8	2	4	0
1 Deployment N = 14	15	15	14	7	7	14	4
2-4 Deployments N = 19	15	14	13	8	6	10	2

**Note:* N = Number of participants who made a comment in each section.

Participants provided overall assessments of the photos they viewed. To exemplify these discussions two Soldiers, a junior enlisted Soldier who had never deployed and an experienced Soldier who had deployed once, directed their comments on a photograph taken of a cemetery (Figure 7). The photo they discussed depicted three members of a U.S. force in a cohesive group and one member who is by himself as they are walking among numerous headstones. During the interviews, both Soldiers suggested that perhaps the U.S. forces were pursuing someone through the cemetery or trying to clear the area. The experienced Soldier elaborated on this suggestion, "or they're just looking through to clear it and maybe make sure there are no explosives and nobody hiding in there" and considered additional threats, specifically from snipers.

Figure 7. Photo discussed by Soldiers that revealed experienced-based reasoning differences.

The junior enlisted Soldier focused his comments on the individual separated from the group and the threat to the lone Soldier stating "That guy by himself is not a very smart idea. They (the enemy) could be all up over here…basically, right here, this is not right when you're clearing anything, you stay together; you don't ever separate." This demonstrated the more procedural and context-free rules to thinking often exhibited by novices (Dreyfus & Dreyfus, 1986). The experienced Soldier was also concerned with the Soldier separated from the group, but provided suggestions for why he separated from the others:

> *[T]his guy is on his own and maybe instead of going on his own, he ought to go with them. Obviously, these guys are clearing around this area…they may need somebody up there, that way if something does happen they have the high ground already so [that the lone Soldier] could see around and watch for anything coming up on them.*

This Soldier was demonstrating his ability to create a causal story about a threat situation (Figure 1, box h) and to hypothesize about possible explanations for why the solitary Soldier was breaking from procedure and taking what the junior enlisted Soldier perceived as unsafe action, demonstrating a more proficient skill level.

The junior enlisted Soldier focused on procedural rules discussing how Soldiers should not enter the cemetery unless they have received permission. The experienced Soldier thought beyond the situational constraints and discussed why this break in procedure might be a good strategy, "I'd make sure that we have high ground in case there's anybody hiding in there as we're going through it, to watch for somebody running around..." This difference illustrated how decision makers incorporate their experience into their assessments of situations (d) to interpret what they are seeing (Dreyfus & Dreyfus, 1986, Ross, et al., 2005). The experienced Soldier's comment also demonstrated that he was able to look at high-priority threat locations based on knowledge (i) by taking action that reduces the threat.

Types of Threats.

Table 10 lists the types of threats mentioned by Soldiers when viewing the photos and the number of Soldiers who made explicit reference to these threats. Soldiers identified these threats spontaneously rather than from a list of threat types, thus similar types are listed separately. For instance, some Soldiers described bombs and explosives while others made more specific reference to IEDs and rocket-propelled grenades (RPG), etc. While Soldiers in each deployment category discussed IEDs most often, followed by snipers, some differences appeared between those who had deployed compared to those who had not deployed. More Soldiers in the deployment groups referenced IEDs compared to those who had never deployed. Soldiers who had never deployed and those who had experienced between two and four deployments both referenced 10 threats while Soldiers who had experienced one deployment refer to 13 types of threats. This may be because non-deployed experienced Soldiers relied on threats they learned about in training or might expect to encounter in a particular situation. Soldiers who have deployed once have a larger list of possible threats. This may simply be due to changing enemy TTPs or may be because they have started to expand their knowledge of possible threats, but have not yet narrowed down the list of potential threats to those that are the most likely. Perhaps the most experienced Soldiers have narrowed down their list of threats because they are better able to filter and sort threats according to relevance and likelihood and may indicate they have more developed schemas and a more proficient skill level (Dreyfus & Dreyfus, 1986).

Soldiers could have discussed any possible types of threats during their interview. Specific enemy and troop tactics such as those discussed in the cemetery scene (Figure 7) are just one example. Other differences between less and more experienced Soldiers concerned their discussion of threats posed by the environment. Less experienced Soldiers often mentioned the terrain. One Soldier stated, "Just the fact that they're around the mountains; the visibility around those mountains is limited. The terrain - it's easy to blend in and get assaulted or ambushed from any angle, from the top." Another typical comment indicated the uncertainty of the situation, as one Soldier stated "High elevation; you're at the bottom of the creek bed and people could be above you. You really don't know what's up here. You might have scouts going every way but, right here, you look like you're by yourself."

Table 10

*Number of Soldiers who discussed each common type of threat**

Threat Type	**Never deployed (*n* = 13)**	**Soldier Experience 1 Deployment (*n* = 14)**	**2-4 Deployments (*n* = 20)**
IED	5 (38%)	10 (71%)	10 (50%)
VBIED	3 (23%)	4 (29%)	0 (0%)
PBIED	1 (8%)	3 (21%)	2 (10%)
Bomb/Explosives	4 (31%)	1 (7%)	6 (30%)
Sniper	4 (31%)	6 (43%)	4 (20%)
RPGs	1 (8%)	2 (14%)	2 (10%)
EFPs	0 (0%)	2 (14%)	1 (5%)
Ambush	2 (15%)	1 (7%)	1 (5%)
Small Arms	0 (0%)	2 (14%)	3 (15%)
Grenade	0 (0%)	2 (14%)	0 (0%)
Mortar	0 (0%)	2 (14%)	0 (0%)
Surveillance	2 (15%)	3 (21%)	0 (0%)
Other	1 (8%)	6 (43%)	1 (5%)

**Note.* Soldiers could discuss more than one type of threat.

Three Soldiers who had deployed once made comments about the terrain; one stated, "A curve in the road was the worst. That's where they seem to hit you the most because they could see your vehicle turn from a long ways." This Soldier's comment shows that he was able to identify high-priority threat locations based on his previous knowledge (i). Another Soldier stated that snipers were a threat and "it's a linear danger; it's an open space and there's more cover outside than where you're at. It could be a vast amount of threats; there are a million different scenarios." The final Soldier said "Maybe it is a high ground so if there's a road here to make sure there's nobody hiding up there - maybe a sniper or something like that." These Soldiers' comments indicated that they were actively trying to identify the threat and create stories about the threat situations (h) while still operating with a good deal of uncertainty as they tried to determine what action they would take.

Finally, two Soldiers who had deployed multiple times commented on the terrain. One Solider made a statement about how open spaces make troops vulnerable to sniper fire. The other created a story to explain how he thought terrain was the biggest threat. He stated:

> *In my opinion, terrain plays the biggest role in everything. It pretty much decides everything, whether there's a bunch of kids and maybe the particular enemy in that area doesn't like them or doesn't like to take out children. IED spots and sniper spots, any advantage point in an ambush and things of that sort.*

He then explained how he might take advantage of the terrain if he were the enemy. "I'd just keep to the right side right there and try to take out part of the road; you could also put one in the mountain right here. That's not a lot of damage to the truck but, again, I'd pile a bunch of dirt and rock on the road and now you have vehicles trapped on either side." This Soldier demonstrated ability to take the enemy's perspective to reason about possible threats and consequences of enemy actions, indicating a higher level of causal reasoning.

Threat Cues.

Less experienced Soldiers tended to discuss specific cues and make general comments about behavior such as "they look kind of suspicious" or "being by himself, doesn't look right." These Soldiers tended to describe suspicious behaviors in general terms, for instance, "I guess the biggest thing would be any specific individuals who brought attention to themselves, just through their actions, just wherever I'm observing at the moment." These Soldiers also mentioned environmental cues, specifically rock piles, garbage piles, buildings with windows, tinted windows, lowered vehicles, and wires.

Soldiers with one or more deployments typically listed threat cues, but also provided more contextual details and interpretations of the cues and situations. Some of the cues discussed were:

- someone sitting in a car which might indicate they have a detonation device,
- crowds of people,
- people who act suspicious such as looking at you then running off to hide or trying to stay hidden,
- piles of junk or garbage,
- animals carrying heavy loads,
- people with bulky or odd clothing,
- anything that seems out of place,
- lights that have gone off,
- telephone poles as markers, spotters,
- damaged road medians or discolored curb,
- wires,
- locals avoiding certain areas, and
- police not doing their jobs.

Many Soldiers in this group also mentioned that any changes they were able to detect might be a threat cue. For example, one Soldier described a threat "If you've been down this route so many times and it's always been the same and then all of a sudden there's a car there just dead." These comments indicate that these Soldiers are aware that the ability to detect change or anomalies in the environment (g) is an important skill.

These experienced Soldiers also reasoned about why specific cues may or may not indicate a threat. For example, one Soldier stated "There is a possibility of an IED somewhere around here, but it's not likely because this is a big puddle. It looks like it just recently rained so they're probably not going to put their electronic stuff out because it'd get ruined so they can't really use IEDs." A few Soldiers discussed why lights might be a cue such as "Lights… sometimes people notice the lights go off when there are things going to happen…Sometimes the lights will be out and sometimes they will just go off too. So it's all variable." These Soldiers were able to incorporate prior information into their decisions (d) and create causal stories about threat situations (h) by discussing their experiences with light cues and the likelihood that they are cues to threat. This suggests they are able to classify cues as threats or non-threats (b) based on the context of the situation.

Strategies for Threat Detection.

Many of the less experienced Soldiers made comments about spotting cues as a strategy for threat detection. They made comments about maintaining alertness, looking for triggermen or spotters, and other non-specific comments such as "There are just different areas that you'd check regularly." One less experienced Soldier constructed a more detailed narrative about a situation depicted in Figure 8 and stated that "If we came up here we'd have the guy step away from the wagon and search the people on the wagon. Have people pull security while you were doing it. Check the cart, check their bags, and you'd go over and check the motorcycle to see if anything looks out of place. Go into the house; clear the house. I guess just talk to the people and see if they know any of them." He continued to explain "We'd walk by a vehicle, look around at the people and find out what they're doing. If they're moving away, something might be up. Find out if it's a suspicious vehicle, deploy your security to look inside and make sure it's not trapped, open up the doors, take a look inside the glove compartment, the console, underneath the seats, and dash. You'd want to pop the hood and trunk to look in there. Look for any wires that shouldn't be there." Finally, this Soldier suggested he would ask locals about any possible threats in the area. His analysis indicates that perhaps he is moving from the novice skill set to that of advanced beginner or competent stages because he is processing the information and searching for plausible solutions within the context of the situation (Dreyfus & Dreyfus, 1986).

Figure 8. Photo that led to discussion with Soldiers concerning threat strategies.

Another strategy recommended by the Soldiers who had one or more deployments was the use of dismounted patrol. One Soldier stated he would "send your dismounts out to find them, to look for wires, and to look for stuff" while another mentioned that dismounted patrols allowed for the detection of a command wire. He said "I actually tripped on a command wire one day and that's how we found it. Luckily, we did that dismounted, walked around and looked for command wire." Many Soldiers commented that they would look for command wire as a way to detect IEDs. This statement also echoed the realization that often no cues were present until the IED detonated. Another mentioned "…I can't say that we looked for (cues to IEDs) because we never actually found an IED before we detonated it. Either it just went off on us or a patroller has already found one and had already blocked traffic."

Soldiers who had deployed once were interested in using the local population as a strategy for threat detection. As one Soldier put it, "[Threat detection] should be with the local people; they give away everything. And usually in populated areas there'll be no threat. I've never had an issue with the population…they'll come and tell you because they don't want [terrorist activity] there just as much as you don't want it there." Leveraging the local populations was a common theme among many of the Soldiers who had deployed. One Soldier with multiple deployments relied on an interpreter to detect threats. He stated that "if you have a good interpreter he'll say 'he's speaking a really odd form of Arabic or he doesn't sound like a local.' So a lot of the interpreters are local, not from the city but from the area, so it'd be like a southerner saying he speaks like a northerner or western…[information like that] just makes sure you look a little closer."

With the exception of the one non-deployed Soldier quoted above, most Soldiers who had not deployed were unable to provide detailed assessments of strategies to detect threats. Only 8 of 13 Soldiers identified strategies. Those who did tended to mention non-specific strategies. Soldiers who had deployment experience often gave richer narratives of what strategies they would take. Additionally, Soldiers who had never deployed did not address topics such as the lack of strategies, using local populations, or dismounted patrol as strategies for threat detection.

Threat Detection Tasks.

Eight non-deployed Soldiers stated that observing situations and environments was a main threat detection task. They made comments about checking the area, people, or objects. One Soldier said "Hopefully, I'd be with other people and I'd say 'keep an eye on them.' And get other people looking around the perimeter, a 360." Another Soldier said "I'd just pay attention to the people, the vehicles around the buildings, to see in the windows, or even the top of the buildings because people get up there and stuff. And I'd pay attention to that a lot." Another Soldier commented "It's just that you have to check people; that is what we were told [in training]. If the people are in your area and they could potentially be a threat then you should check them." These less experienced Soldiers largely described the tasks from a passive point of view and focused primarily on tasks reinforced through training, as the last Soldier indicated.

While less experienced Soldiers focused on scanning and observing the environment, the Soldiers who had deployed multiple times often took a more active stance in their threat detection tasks. One Soldier described searching someone riding a motorcycle and said "We'd stop them and maintain standoff, have him park his motorcycle, get off, and lift his arms up into a circle. Try and determine if he was a threat or not…we'd just tell him stop and then we'd have him open his hands and make sure he didn't have any trigger mechanisms or anything like that in his hands or running through his sleeve. We'd see if the rest of his coat fell down, like when he stood up see if his coat fell down as opposed to staying up, bulking, you know." This Soldier created stories about the threat situations (h) and incorporated prior knowledge to hypothesize about what might happen and what actions he might take (d). This Soldier mentally simulated a situation in which the individual posed a threat (h) "We'd continue standoff and then go check it out…I'd look at it with optics this way, and then I'd make a big circle around over here, and then I'd look at it with optics this way, and I'd get that dude on his face. No chance he's going to blow me up while he's laying on his face." This comment also demonstrated ability to take action to the better classify the threat (b) and take action to reduce the threat (e). He continued to suggest what might happen if they were attacked and constructed a rich narrative that included checking for a secondary device, establishing security, using dismounts to search for command wire, and maintaining visual contact and communication. His ability to construct a rich description demonstrates many aspects of the threat detection loop including being able to encode details about the situation (a), detect changes or anomalies (g), balance his decision with the need to gather additional information (f), and identify the appropriate course of action (e).

Some Soldiers with one deployment focused on tasks that involved understanding the overall context of the threat. One Soldier described presence patrols as a task where "you're just looking around, checking for things that could be bad, meeting people and you'll be meeting high-ups, mean low-down people, everything - just making your presence known." Another Soldier thought that one of the most important tasks was to interact with locals to understand the broader situation. He stated "The biggest thing would be to know all of the rumors going into a situation; that this guy may or may not know that we know about him. Essentially, whether he has ties to foreign fighters, al Qaeda, Taliban, or whether he's like one of the most trustworthy, most loyal American supporters that the country has." Another Soldier described the difference in detecting threats between conducting a presence patrol rather than patrol based on a tip. He said that during presence patrols "You still look for threats, but you're really going to treat the Iraqis, you'd talk to them, just like a regular person. You wouldn't search them, it's more of a trusting type thing." Soldiers who deployed once focused on how the tasks fit into the broader context of the situation and explained that knowledge of the local allegiances determined how they went about threat detection. Often, the Soldiers with no deployment experience focused on the procedures they would engage in to stay safe without taking into consideration the large goals of community relationships and intelligence gathering.

Threat Detection Skills.

Only two non-deployed Soldiers commented on skills related to threat detection. One mentioned that he relied on life experience and the threats encountered in everyday life to determine threats while the other engaged in thinking like the enemy. He suggested that it would be easy to hide something in a sack of papers that a donkey was carrying. He said "Yes, it seems like it'd be real easy to do that, anyway, if I was going to hide something it seems like right at the bottom of one of those sacks would be perfect." He mentioned that seeing a scene like this would raise his suspicion level because "it just seems like it provides (the donkey owner) an opportunity to get close without actually having to go through security points or anything like that." While the Soldier was thinking of places the enemy might place an IED, he focused on the ease of emplacement and the chance that the situation might go unnoticed. These statements indicated that this Soldier is moving to advanced beginner stages of skill development as he incorporated situational elements into his threat assessment (Dreyfus & Dreyfus, 1986). Exercises in thinking like the enemy promote the development of these skills and assist Soldiers to advance beyond novice stages of skill development.

One Soldier who had deployed multiple times took a different perspective when thinking like the enemy as he discussed the outcome of the threat (Figure 9) rather than focusing on emplacing an IED. "They have vehicles and why not plant an IED right here; even if it doesn't take out the vehicle it's going to take out the road, cut the lines in half so vehicles can't get back and forth. The vehicle will roll down that hill as easy as hell…and even if the whole road doesn't go or the vehicle rolls down then, again, you still have a giant gap and this (Soldier) can't cross, that one can't cross." This Soldier demonstrated causal reasoning about the threat situation (h) by suggesting that IED placement could result in multiple outcomes. Another Soldier considered enemy strategy stating he would be unlikely to drive down a road "because of all this overturned [dirt], [the enemy] could be…trying to funnel you into a certain side of the road or whatever." Both Soldiers were trying to anticipate the intent of the enemy when thinking about what tactics the enemy would employ in each situation rather than solely focusing on how one might emplace an IED.

Figure 9. Photo that led to discussion with Soldiers concerning thinking like the enemy as a threat detection skill.

Challenges in detecting threats.

Comments made by two of the four less experienced Soldiers indicated they had incomplete mental models. One Soldier said it would be difficult for him to determine which cues to notice "It's hard for me to say at this moment. I mean, in the moment you'd probably be able to identify stuff here and there, but talking about it from this point of view I don't know exactly what I'd be looking for; just something that sticks out from the rest of them." The other Soldier thought it would be difficult to notice behavioral cues and stated "People acting suspiciously; I don't really know very much about that. I mean I can sort of tell; just life experience, but if I could get some training on how to read people a little better it'd be helpful." Both statements suggest that while they may know what general cues to look for such as some unusual or suspicious behavior they lack the mental models to articulate what these cues actually mean.

Many of the Soldiers who deployed once took a different approach to noticing cues. They often commented that most changes in the environment were not indicators of an attack and that because enemy tactics changed often it was hard to distinguish relevant from irrelevant cues. One Soldier stated "[The enemy is] so creative, [their tactics] change every day so you can't really worry about it. All you have to do is your job." Another Soldier stated "Things change all the time. I mean you could go down a route six times and have cones in different areas and all at these random checkpoints and stuff." He went on to create a narrative about how enemies do their homework including using camera operators and note takers to watch how the U.S. forces respond to an initial attack so they can set up a secondary attack as the quick reaction force (QRF) or medevac to arrive on the scene. This suggests that these Soldiers have ideas of what cues may indicate attacks, but the realities of the situation require them to look beyond specific cues that may not be consistently relevant (b). To do this, they need to encode details about the situation (a), engage in causal reasoning (h), and balance decisions with information gathering (f).

Soldiers with multiple deployments also said it was difficult to notice cues because the enemy changed tactics often as a way to reduce their predictability. One Soldier said "I really don't like looking for IEDs…too many places to put it, to hide it, hard to find, and not enough manpower." Another Soldier stated that "when you're on patrol you're concerned about everything…and, of course you can't look at everything, you're going to miss something…" This same Soldier went on to say "A lot of the younger guys who have never been [deployed], and some of them have been to classes, then, yes, the only thing they're going to look for is stacked up rocks and overturned dirt. Yes, one spot is overturned, they're going to look at the small stuff, they're not going to look at the overall [picture]…that's what I'm seeing when I look at this. I'm seeing that anything can be a threat." These Soldiers understand the role experience plays in identifying threat and non-threat features (b) as well as appropriately encoding details about the situation (a). These more experienced Soldiers are able to focus their attention on relevant cues and reason about what cues are not important or relevant in the moment. They are better able to organize and prioritize information based on their experience which research indicates is a characteristic of expertise development (Ericsson & Charness, 2004).

Across both groups of Soldiers who had deployed, the reliability of information posed a specific challenge. A Soldier who deployed multiple times gave a mixed response when asked whether locals were a good source of intelligence. "Sometimes they were, sometimes they weren't. I guess it really depends. I mean a lot of them just looked at you like you'd know they knew…if they were looking at you like they wanted to stay out of it, they're not going to tell you anything. It's not necessarily that they don't want to tell us, it's that they're scared to tell us." Another Soldier stated "You'd go through sectors where we'd just show up and talk to the sheik and he'd be like 'There aren't any IEDs,' like there really aren't, or he'd tell you three or four spots, kind of rat the Taliban out. And then you'd go to other sectors and it's not as reliable because that guy is less supportive of American and the Taliban forces are stronger in his area, so he can't support more even if he wants to."

Solutions.

Less experienced Soldiers did not provide many solutions for improving threat detection performance. Little difference existed between Soldiers who experienced one deployment and those who had been on multiple deployments. Across both groups, Soldiers stated that constant alertness and attention to detail were critical to effective threat detection. One Soldier suggested that foot patrols are an easy way to reduce complacency while increasing mobility and avoiding attacks. Two Soldiers made comments about the importance of making connections to local populations. The first Soldier stated "If you're working well with the locals, you're being generous to them, and you're working hand-in-hand with them, you'll have no problems in that area, there'll be no issues in that area." The second Soldier stated "Let's say this is part of a sector that you're responsible for, I'd probably know these guys standing here and I would have a reasonable level of trust, you know what I expect whether it is something that would be a big threat to me or not." That Soldier discussed how they might counter an enemy threat "As a mounted force, if I had other sectors of the city secured, at least the parallel street, to put forces at the viewpoint of the camera, then kind of flank around to the rear point of the field of focus as well. That would be ideal; we're basically taking away their escape route." Again, these Soldiers are considering strategies to reduce threat levels rather than simply spotting cues.

Summary of Research

This research examined how less experienced and more experienced Soldiers performed experimental exercises related to threat detection and responded to situations that contained potential threats. Some of the key findings suggest that time, threat relevance, and expertise played a role in Soldiers' performance. Data in the prioritized threat search exercise demonstrated that novices were more susceptible to time pressure and the number of deployments increased accuracy slightly under time pressure. Results in dynamic threat detection revealed that Soldiers were able to infer threat-relevant locations and appropriately focus their attention to those areas. Additionally, all Soldiers had a tendency to identify targets in threat-relevant locations. Finally, the change detection exercise indicated that Soldiers were able to identify changes related to threats.

An analysis of the interviews revealed differences in the number of times less experienced and more experienced Soldiers discussed strategies for threat detection, threat detection skills, challenges in detecting threats, and solutions. Further analysis suggested that there were differences within all of these broad categories, ranging from topics of discussion to the content of these discussions. Novices typically responded in a rule-based fashion, relying on things like context-free cues or threat, whereas experts constructed rich narratives and scenarios that allowed them to describe their assessments of situations in ways that were more complex. Taken together, these findings suggest ways that less experienced Soldiers differ from experienced Soldiers. We can use these differences to train less experienced Soldiers to improve their ability to identify relevant threats, detect relevant changes, and develop causal reasoning skills applicable to the operational environment.

One limitation of the current research was a lack of clear expert and novice groups. Soldiers ranged from zero to four deployments. Soldiers fell into groups of relatively even numbers across deployments when categorized as zero deployments, one deployment, and 2-4 deployments. Using deployments as a proxy measure of experience was logical for this research and other criteria of expertise, such as years in the military and rank correlated highly with number of deployments. Conducting research that had two groups with clearly delineated levels of experience would allow for a clearer analysis of experience differences. The lack of distinct experience levels may have contributed to a lack of statistical significance in some of the analyses.

Exemplar Training Development

Design.

Results of the computer exercises demonstrated the utility of these exercises as potential training methods. In the prioritized threat search exercise, time pressure negatively affected the performance of Soldiers with zero deployments, but had little or even a positive effect on Soldiers with one or multiple deployments. Targets in threat-relevant locations were located faster and with greater accuracy. However, no statistically significant differences were found based on experience. This finding indicated that Soldiers, even in threat search exercises using static photos, directed their search to relevant threats rather than to random locations on the photo making this a useful stimulus for training. Similarly, in the change detection exercise participants noticed threat-relevant changes rather than threat-irrelevant changes.

The interview analysis provided insight into the reasoning of less and more experienced Soldiers. As expected, Soldiers with less experience tended to make context-free procedurally-based statements whereas experts constructed rich narratives to describe their assessments of situations. This analysis revealed differences in the number of times less experienced and more experienced Soldiers discussed strategies for threat detection, threat detection skills, challenges in detecting threats, and solutions. These narratives indicated that less experienced Soldiers did not have the mental models to draw on to interpret the situations in the photos even if they could identify relevant threats. Based on this information, the training incorporated reasoning exercises that prompted Soldiers to deliberate over threat cues and use information about the situation and environment to reason about likelihood, threat relevance, and severity. This training focused on helping Soldiers become more able to detect and interpret threats in the context of situations, thus allowing them to broaden their experience base and develop applicable mental models.

From the research data, four learning objectives were identified. These learning objectives map onto the expected behaviors of experienced threat detectors identified as part of the threat detection loop (Figure 1). For instance, the initial exercises focus attention on encoding details to identify and classify relevant threats. The reasoning exercises increase ability gather evidence to determine threat importance and impact. The change detection exercises were developed to increase the perception of changes and improve the ability to determine the relevance of the change (Table 11).

Table 11

Relationship between learning objectives and the threat detection loop

Learning Objectives	**Step in Threat Detection Loop**	**Threat Detection Loop Behaviors**
1. Demonstrate an improved ability to identify relevant threats in a variety of situations.	• Monitoring, vigilance, and search activities	a) Encoding details for immediate or delayed test
2. Distinguish between threat-relevant and threat-irrelevant cues in time-limited situations.	• Identify/classify threat or non-threat	b) Ability to classify threat vs. non-threat features i) Ability to look at high-priority threat locations based on knowledge
3. Recognize the importance and potential impact of each detected threat.	• Identify/classify threat or non-threat • Gather evidence to ID threat	c) Ability to adapt decision selectivity based on information f) Ability to balance decision with information gathering h) Ability to create causal stories about threat situations
4. Identify threat-relevant changes in the environment.	• Change or anomaly detection	g) Ability to detect change or anomaly

To determine which photos to use in the training, 10 instructors and Soldiers from Fort Hood reviewed the 44 photos and selected the 10 most and 10 least preferred choices to incorporate into training. The instructors described the most probable threats depicted in 5 of their top 10 photos along with reasons why those threats would be the most difficult to detect. Soldiers in the experiment chose some of the same photos as the instructors. Of the photos selected by Soldiers in the experiment, the instructors also rated many in the top 10. Focus was given to photos that more than one Soldier commented on because they provided threat cue locations, annotation, and interview data that would make up the training content. The photos were then reviewed for training applicability, photo quality, and the ability of the photo to provide training content that met the learning objectives. The interview data was matched to the final set of 11 photos and then photos were selected that would apply to the threat search, reasoning, scenario, and change detection exercises (Appendix C).[8]

To guide the development process, storyboards provided the content and photos that appear on each screen of the computer-based training (Appendix D). The purpose of the storyboards was to map out the entire course. Military subject matter experts reviewed the content and created the questions for the Soldiers to answer and feedback they would receive. Soldiers also were given feedback about their threat search activities, response time, and identification of threat relevant cues.

The exercises in the training take a crawl-walk-run approach. The first series of exercises involve threat searches. Soldiers first view photos with threat cues already marked and click on these cues to read about what the threat is, why the threat is relevant, and common enemy tactics. Soldiers then view photos and click on potential threat cues. If the places they click are threats, annotations pop up, again providing information about those cues. They then engage in a timed threat search exercise (Figure 10).

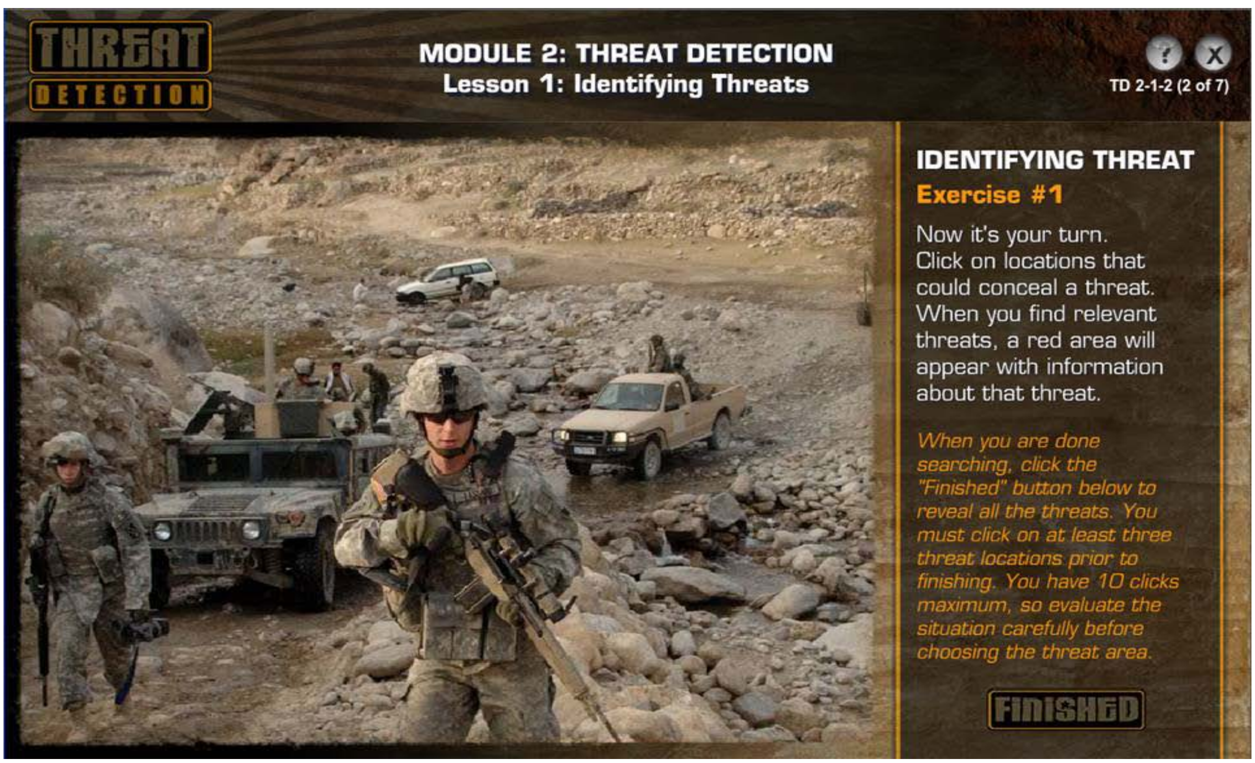

Figure 10. Screenshot of Threat Search Exercise.

[8] Six instructors selected three of these photos in the top 10 (each of these photos was selected once in the bottom 10) and four selected one photo in the top 10 (none selected it in the bottom 10). One or two instructors chose five of the photos in the top 10 (with one or two selecting them in the bottom 10). Two photos did not appear in the top or bottom 10.

Following the threat search, Soldiers view photos with questions that require them to reason about the situations presented and evaluate the threats in context. They engage in critical thinking about the potential threats and read several possible solutions (Figure 11). They also read comments made by experienced Soldiers who discussed the photos during the interviews.

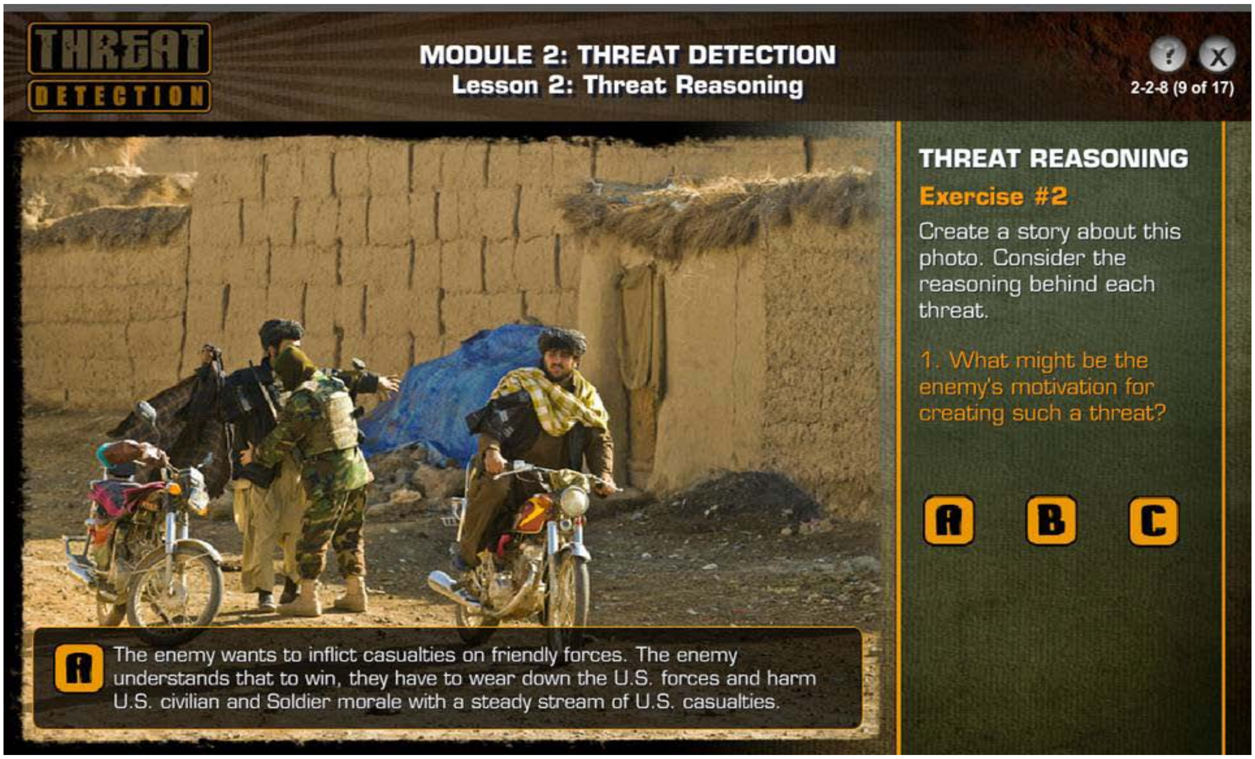

Figure 11. Screenshot of Reasoning Exercise.

Finally, Soldiers complete the threat search and reasoning exercises by reading scenarios that frame the context of the photos and then consider that context to identify threats and determine relevance (Figure 12). Soldiers also complete two change detection exercises during the training, one in the context of a threat search and one in the context of causal reasoning.

Development.

The Instructional Systems Design (ISD) process informed the development of the computer-based training (CBT) materials. The data and storyboards contributed to the development of the look, content, and functionality of the training product. A Graphical User Interface (GUI) was created, edited, validated, and verified and then a Sharable Content Object Reference Model (SCORM) compliant version of the CBT course was developed. When developing a SCORM compliant CBT course, the major sections of each module, such as introductions, lessons, and summaries are wrapped into their own Sharable Content Object (SCO). The SCORM compliancy allows training delivery to a variety of Learning Management Systems (LMS) that the military currently uses.

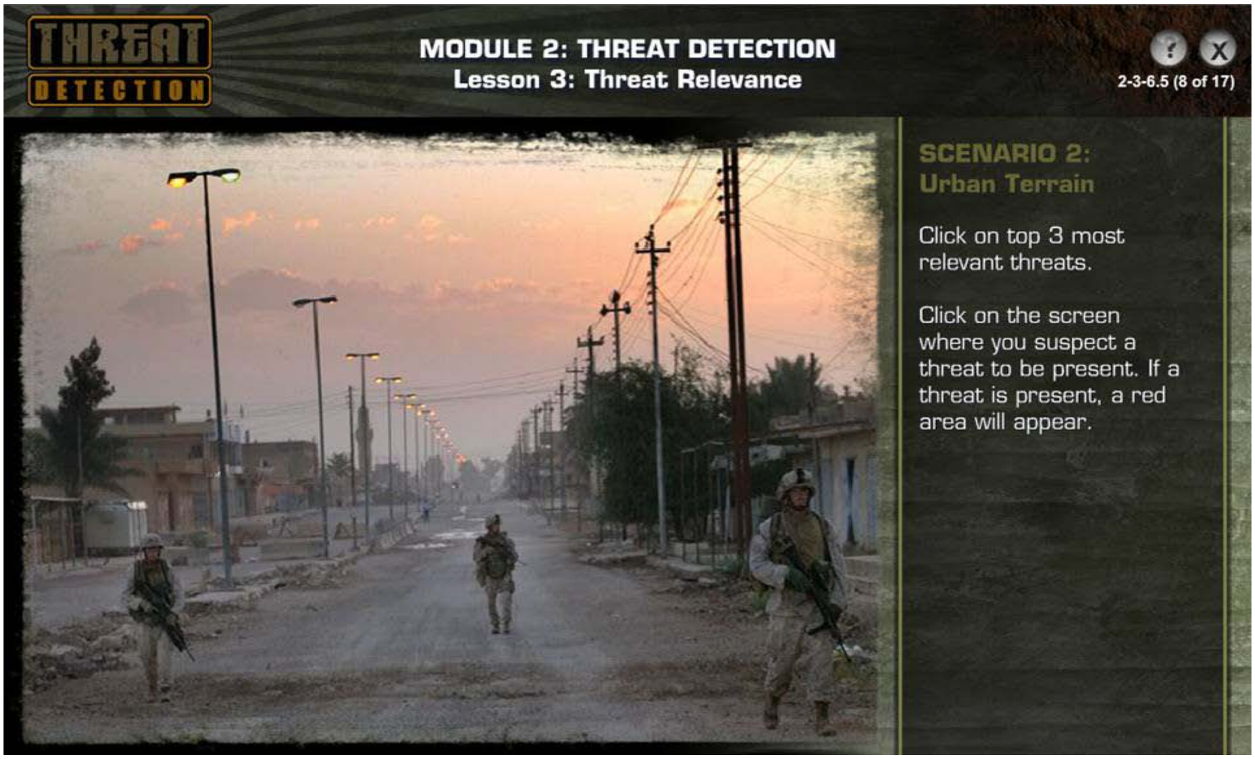

Figure 12. Screenshot of Threat Relevance Exercise.

While in development, subject matter experts (SME) could view the CBT course on an internal server to provide comments, request changes, and check the course for functionality. The evaluation took place throughout the ISD process first with reviews of the storyboards, then through initial reviews of the introduction slides, and after that, a formative evaluation process. After the evaluations and final approval of the course, the CBT was placed on an external server or the client-provided LMS and CD/DVDs were created for distribution.

Formative evaluation.

Three instructors at Fort Hood, TX, completed two evaluations of the training while it was under development. They reviewed an early draft of the trainer that included the introduction and the pre-test exercise. Their early assessment included suggestions for improving the narration, providing feedback at the end of the exercise, and collecting demographic information. These reviewers also provided feedback about the CBT format and design. These reviewers conducted a second evaluation of a more advanced version of the training that included all the content and exercises, but was missing some functionality. The reviewers answered questions specific to the training product and addressed issues of training implementation. The following questions were included.

- In terms of being able to interact with the product, are there certain navigation features that need improvement (because they weren't easy to use/navigate)?
- Do the scenarios and photos present realistic depictions of frequently encountered situations in theater? If not, do you have recommendations for scenarios and photos to include?

- Who would be the best audience for this trainer: new Soldiers prior to their first deployment or as a refresher for Soldiers who are deploying after one or more previous deployments? Why did you choose that group?

Overall, the responses from the three evaluators were very positive. Some feedback addressed functioning issues within the trainer that were addressed in the final version. The reviewers appreciated the sense of urgency that time restrictions within the trainer presented stating that although it is not the same as being in the actual situation, the restriction modeled time stress to some extent. Other responses addressed the question of who should use the trainer. Suggestions included using the trainer for new Soldiers so that they can learn important skills before deploying, but also using the trainer for Soldiers who need to refresh and sharpen skills before redeployment. Finally, the reviewers suggested that the trainer in combination with an instructor would provide students with additional insight to enhancing threat detection skills.

Suggestions for Methods Refinements and Extensions

Our current methodologies used static imagery to both identify and convey threat signals to Soldiers in the experiments and training and used overt annotation and search behaviors to collect information regarding threats. This had some practical advantages in that Soldiers could study imagery closely without time pressure and they could make annotations in detail. However, new technologies may augment and improve both data collection and training products in three important ways: 1) use of dynamic video imagery for improved data collection and training, 2) use of eye-tracking hardware and other means to identify directly the locus of attention during threat detection behavior, and 3) use of immersive environments to improve training realism.

Dynamic Video Imagery. The use of static imagery allowed us to use high-resolution stimuli which contained considerable detail that is often lacking from the video footage of threat situations. As a result, our methods identified threat cues that were primarily static such as features of the terrain or persons in the scene that might be a threat. However, our interviews identified a number of threat cues that are dynamic rather than static. These included subtle interpersonal cues such as where a person is looking or how he or she is walking, ways that a vehicle bounces or “drives suspiciously,” and so on. Soldiers can only identify these threat cues in dynamic video imagery and research might require fundamentally different elicitation methods to uncover this type of information. To the extent that it is possible to obtain appropriate video and design proper data collection experiments, training can be further augmented so that it can cover both static and dynamic threat cues.

Attention-tracking and Eye-tracking Hardware. Several of the research exercises used behavioral cues (mouse clicks or identification response times) to help identify where Soldiers were directing their attention. Software or hardware systems could augment these exercises to allow closer monitoring of visual attention. For example, simply recording the location of the mouse cursor during a search can give an accurate picture of where a Soldier looks, but an even more promising method would be to monitor eye movements to identify exact locations of search activities. Eye-tracking technologies hold particular promise if combined with video imagery because research can begin to understand more detailed visual search and attention strategies during threat detection. This method would be particularly useful to identify expert threat search strategies in complex visual environments making this a useful technology for research and for training.

For example, there is some evidence that eye-tracking technology encourages non-experts to adopt visual search strategies that are more similar to those of experts. Research by Sadasivan, Nalanagula, Greenstein, Gramopadhye, and Duchowski (2004) used an overlay of an expert's eye movements on an aircraft that required inspection. Participants who received this type of training demonstrated greater improvement in their visual search performance compared to those who did not receive training. This feed-forward training allowed participants to rely on the expert's search strategy early in the visual search process, thereby adapting to a more effective search technique. Further research by Nalanagula, Greenstein, and Gramopadhye (2006) used three types of displays involving eye-tracking to improve performance when detecting defects in circuit boards. These three displays included a static display representing the expert's eye path and general areas of interest, a dynamic display that highlighted the expert's areas of interest in the order performed during visual search, and a hybrid display combining both static and dynamic features. Both the dynamic and hybrid display improved the number of defects participants were able to identify. Eye-tracking technologies may be used to both identify search differences between novice and expert threat detectors and to train visual search strategies and improve skills. With the advent of reasonably cheap eye-tracking hardware, training facilities can use this technology as a method to improve training and measure skill level, and researchers can leverage these technologies to understand threat detection strategies.

Immersive Training Environments. A third limitation of the current methodology and training is that it focused on perceived threats rather than actual threats. The imagery used in the research stimuli and training did not contain actual attacks or IEDs. While the purpose of the exercises was not to detect actual threats, but to improve the cognitive skills associated with threat detection, it may also be valuable to create immersive environments that simulate sequences of events that result in finding and disrupting threats and dealing with the consequences of undetected threats. Training threat detection in field environments provides opportunity for Soldiers to move through situations and scan 360 degrees from a first person point of view. The current prototype offers the crawl and walk stage of threat detection training while immersive training environments offers the run stage of learning.

At least three types of immersive environments could emerge from this research: live training, video exercises, and first-person virtual training. Video-based and live training could be similar in the scenarios they present and the skills they exercise. Video-based training provides opportunity to present select scenarios that students can review multiple times and in conjunction with presentation of knowledge-based training and knowledge checks (i.e., test questions, and critical thinking exercises). Live training allows students to engage in actual threat detection exercises both cognitively and physically while providing a safe environment to refine skills and learn from mistakes. The data collected thus far can contribute to the creation of training scenarios and feedback guides for use in existing live training such as current Lanes Training Exercises (LTX), Field Training Exercises (FTX), or similar skill training events. Video-based training can leverage live scenario materials as a basis for selecting dynamic video imagery that would drive off-line training via computer or classroom settings. Finally, developing virtual environments would allow for dynamic generation of threats, allowing situations to replay so students can identify threat cues they missed and engage in after action reviews etc. Virtual environments also allow for automated feedback and dynamic generation of content.

Conclusion

The series of research phases conducted to understand Soldier threat detection provides a better understanding of how Soldiers manage attention, process information, and reason about events they encounter in the OE. The first three phases of this research provided insight into the key threats Soldiers consider important and clarified the difficulty Soldiers have in distinguishing ambiguous cues from certain cues when searching for threats. Data from interviews with experienced Soldiers enabled the creation of a threat detection loop model and identification of the behaviors necessary for proficient threat detection. The outcome of the computerized exercises was stimuli for the final research that included key threat locations and cues in photos and critical situational factors that influence threat relevance. The aim of the final research phase was to compare the threat detection performance of less and more experienced Soldiers. This research demonstrated the cognitive skills Soldiers employ when searching for threat-relevant cues and changes in situations with and without time pressure. Interviews also provided data that mapped onto the threat detection loop and contextual details that informed our knowledge of the threat detection process.

While all of this research provided contextual detail about how Soldiers think about threat cues, threat detection activities, attention management, and search priorities, the final research phase contributed empirical evidence of Soldier threat detection abilities. This research showed that time pressure influences Soldier ability to detect threats with fewer threats being detected when under time pressure. These results provided some indication that experience reduces the effects of time pressure, but this effect was small and thus more research is required. Regardless of experience, Soldiers focused their attention toward detecting relevant threats compared to irrelevant threats. They were more accurate and responded faster to relevant threats indicating that targeted searching in relevant locations is a component of threat search exercises. While experience did not mediate this effect, the interview data indicated that Soldiers with deployment experience had a deeper understanding of why threats were relevant and under what circumstances threat relevance would increase or decrease. They were able to construct stories around the threats, reason about various action choices, and hypothesize about potential outcomes.

The change detection exercise was one of the more informative concerning Soldier ability to determine threat relevance. Although results revealed a high false alarm rate when trying to find changes in the photos presented, when Soldiers accurately identified changes the majority were threat-relevant changes. This finding adds to the existing change detection literature by demonstrating Soldier ability to notice changes at rates greater than chance. Previous research would suggest that the Soldiers should have a difficult time detecting changes. Change blindness is a phenomenon where individuals are incapable of detecting salient changes in their visual environment (O’Regan, 1992; Rensink, O’Regan, & Clark, 1997; Simons & Rensink, 2005). Previous research has demonstrated that observers fail to notice large changes made during eye movements, across a flicker paradigm, during repeated viewings of the visual scene, and when conversational partners changed during a real-life interaction. Our research demonstrates that at an applied level Soldiers demonstrate some ability to detect change above chance levels.

Researchers have identified some situations that mitigate change blindness. Hollingsworth (2004) and Brady, Konkle, Oliva, and Alvarez (2009) suggest that intentional encoding enables individuals to attend to changes. However, in the current research, Soldiers received no explicit instructions to suggest they should study the photograph for subsequent testing. The test to detect changes was a surprise for these participants and their performance suggests an enhanced ability to detect changes. Further, it should have been difficult for Soldiers to detect changes because the subsequent testing after the target picture provided significant interference. Makovski, Shim, and Jiang (2006) tested change detection ability in natural scenes after presenting blank, visual, or auditory delays and requiring participants either to view passively the delay screens or attend to the information in the delay. Participants who attended to the delay information had a significant reduction in their change detection ability. Because information presented between the target photograph and the changed photograph required Soldiers to attend to a significant amount of information, it was expected that they would have difficulty detecting changes during the second presentation of the photos. Further research should attempt to provide an explanation for this finding.

Experts have been shown to detect changes more often than novices do when the change is related to their domain of expertise (Jones, Jones, Smith, & Copley 2003; Werner & Thies, 2000). In the current research, we found no differences in change detection performance based on experience. The data did not provide insights into why no differences existed. It could be that general training related to detecting threats made Soldiers aware of the potential for change in their environments and thus they were attuned to looking for changes. It could also be that threat-relevant cues are emotional stimuli for Soldiers and those cues captured their attention (Mayer, Muris, Vogel, Nojoredjo, & Merchelbach, 2006; Peira, Golkar, Larsson, & Wiens, 2010; Vuilleumier, 2005) thus making the presence or absence of such cues salient. It may also be that the distinction between the experienced and novice groups was not clear in the current research. Future research should attempt to identify the cause of these findings.

Results of this research provide an increased understanding of threat detection and directions for future research and training exemplar development. The current training uses static images and exercises developed during research that also used static images as stimuli to inform our knowledge of Soldier threat detection. Future research and training should explore the use of video images and eye tracking to gather data to infer perception and attention processes and to train threat detection in complex and dynamic environments. Soldiers of various skill levels tend to focus on relevant threats; however, experience adds context and reasoning to the threat identification process. Future training should continue to highlight the causal reasoning and critical thinking components of threat detection. This research indicated that Soldiers have ability to notice changes, but this ability was limited relative to the high false alarm rate. Although change detection accuracy was not random, it may be possible to improve this existing skill with targeted training.

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Appendix A

Demographic Questions
Fort Hood - 13-15 December 2010

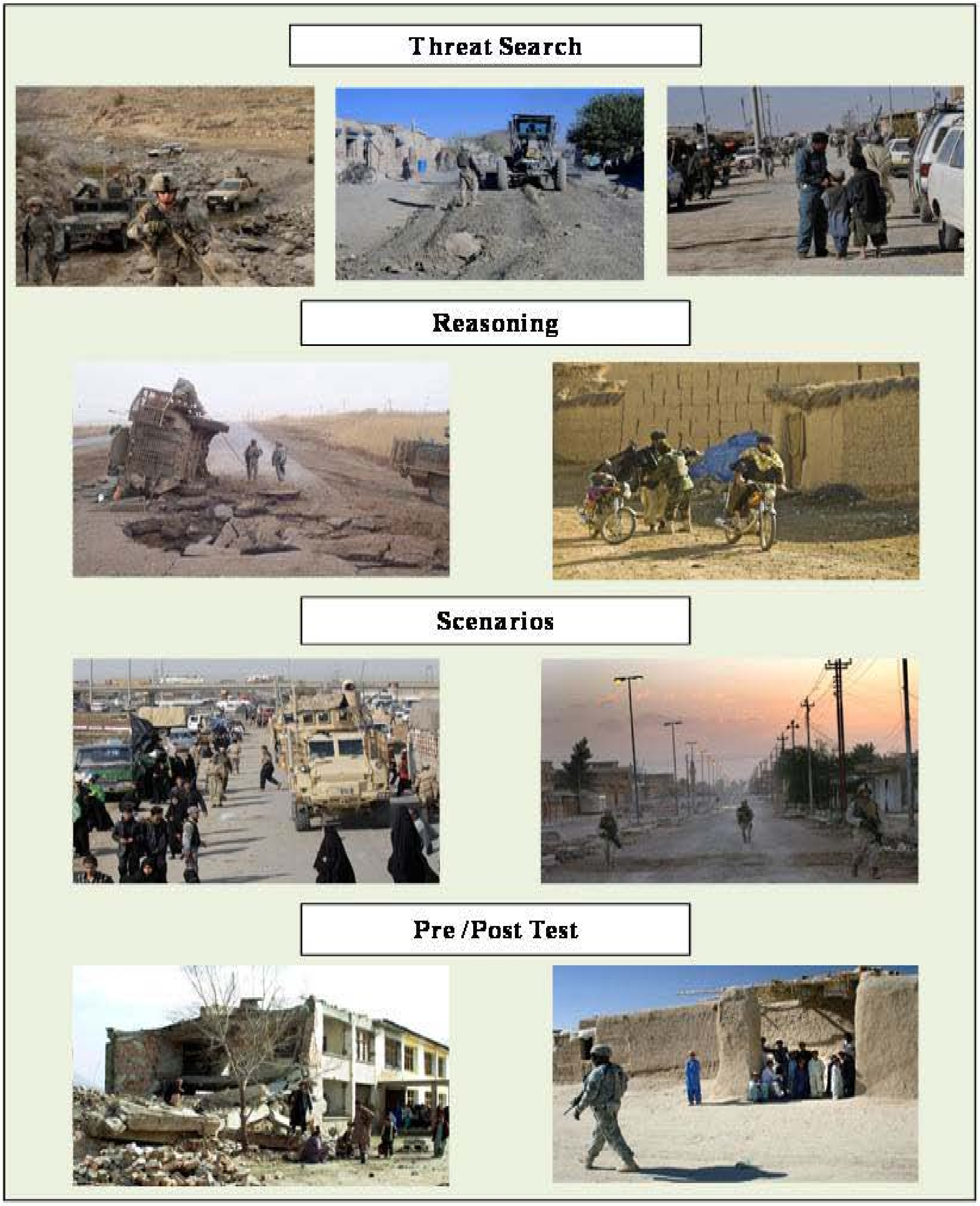
1. Time in service (years)
2. Current rank
3. Time in current rank (months)
4. Current MOS
5. Age
6. Have you ever deployed? Yes No
7. How many times have you deployed?
8. Location of most recent deployment (city or cities and country)
9. MOS while on most recent deployment
10. How often did you go outside the wire on your most recent deployment?
    Never Less than once a month Once a month More than once a month
    Once a week More than once a week Everyday
11. Describe some of your duties during your most recent deployment:

Appendix B

Overlay indicating locations Soldiers clicked on to identify potential threats

Appendix C

Photos selected for the threat detection exercises



Change Detection

Appendix D

Storyboard example used in training exemplar development

Course:	Threat Detection Skills Trainer		
Module:	Threat Detection	TD	TD2-1-2
Lesson:	Identifying Threats	2	
Segment:		1	
Page Title:	Identifying Threat Exercise #1	9	
Child Page:			
Objective:	1) Identify relevant threats in a variety of military patrol contexts		

On-Screen Text:

Now it’s your turn. Click on locations that could conceal a threat. When you find relevant threats, a red dot will appear with information about that threat.

When you are done searching, click the “Finished” button to reveal all the threats. You must click on at least three threat locations prior to finishing. You have 10 clicks maximum, so evaluate the situation carefully before choosing

Narration/Closed Captioning: Narrator

Can you find the relevant threats in this photo?

Graphics: (P – photo; G – graphic; F – flash animation; T – table/chart/graph; V – video)

Use photo: Clean 34 from treat-hires folder.
Use information from Threat Photos-Annotations: Slide 06 for threat areas descriptions.
(Place the red dot in the middle of each threat area.)

Audio:

Knowledge Check: **Remedial Screen:** *Page ID*

Correct Feedback:	*Provide the number of clicks the student made and the number of threats found*
1st try incorrect:	
2nd try incorrect:	

Explanatory Information:

When Soldiers click on threat spots, show a red dot in that spot. The spot should remain visible.
Make each red dot a pop-up of threat’s description, with ability to click and close
After student finishes, show all red dots and pop-ups. Do not allow them to click finish until they have made at least three clicks

Branching:	Back:	Next: